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St. Marys River

Shoreline Erosion and Shore Structure Damage

1980 Closed Navigation Season

February 1981

Corps of Engineers

U.S. Army Cold Regions Research and Engineering Laboratory

Hanover, New Hampshire 03755

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Traditionally, navigation on the St. Marys River closed for winter from mid-December to mid-April. Subsequent extension of the navigation season during the demonstration program to include winter months resulted in complaints of shoreline and dock damage along the navigation channels. Although studies were initiated to examine the potential for navigation-caused damage, information on damage during a navigation-free winter was lacking. The St. Marys River system was examined during the 1979-80 limited navigation season under relatively undisturbed conditions. This report examines potential navigation-related damage mechanisms and presents data from the closed navigation season. Results are then compared with information collected during previous periods with winter navigation.

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INTRODUCTION

During the period from 1961 to 1970, navigation on the St. Marys River closed for the winter between 14 December and 11 January and reopened between 1 and 17 April. Subsequent extension of the navigation season beyond the traditional dates resulted in complaints of shoreline and dock damage along the navigation channels. Under the general authority of the Great Lakes and St. Lawrence Seaway Navigation Season Extension Study (Public Law 91-611, Section 107(b)), studies of shoreline erosion and structure damage due to navigation in ice along the St. Marys River were undertaken.

During these studies one of the problems in determining the relative importance of navigation on shoreline erosion and dock damage has been the lack of information on such damages during a navigation-free winter. Since limited navigation was planned during the 1979-80 winter season, it was felt that it would be an opportune time to examine the St. Marys River system under relatively undisturbed conditions.

The St. Marys River was ostensibly closed to navigation from 15 January to 24 March 1980. Actually the U.S. Coast Guard carried out some limited activities during that period, including seven trips by the icebreaker Katmai Bay and one trip by the icebreaker Mackinaw.

As a starting point in discussing this past winters findings, it should be helpful to discuss the effects of shipping determined rom previous work.

BACKGROUND

The degree to which the shorelines and shore structures of the St. Marys River are subject to the ice-related damage varies greatly according to the manner of ice action. In addition, there are several ways in which vessel passage can affect sediment transport and dock damage including direct movement of ice in contact with vessels, propeller wash, wave action and other hydraulic effects.

Winter navigation, by disrupting the normal ice cover characteristics, may aggravate any natural ice-related damage. Conversely, an ice cover may alter and even amplify the effects of navigation on system hydraulics and influence any resultant damage.

The significance of these various effects depends on a number of local conditions such as the bathymetry, water levels, soil conditions, ice conditions, shore and shore structure composition and geometry, and the presence of other natural agents such as ambient water currents or waves.

Specific sites were studied during past navigation seasons to gain an understanding of the mechanics of the interaction between large scale navigation and the hydraulics of a river system. This mechanistic approach is required since vessel related effects consist of short periods of intense and rapid activity between long periods of relatively mild conditions. In addition, until recently few ships have operated through the entire winter.

Hydraulic Effects of Ship Passage

Although ship waves and other hydrodynamic effects of vessel passage have been studied in terms of vessel maneuverability and power requirements, the effects of vessel passage are not yet understood in terms of natural flow patterns and distribution, and adverse environmental effects. Information for periods of ice cover is almost nonexistent.

When a vessel is in motion, even in deep water, the water level in the vicinity of the ship is lowered and the ship with it (vessel squat). For the same ship this effect increases as vessel speed increases or as water depth decreases. When a ship enters restricted water areas, there is considerable change in flow patterns about the hull. The water passing beneath the hull must pass at a faster rate than in deep water, and as a result there is a pressure drop beneath the vessel which increases vessel squat. In a channel which is restricted laterally, this effect is further exaggerated. A vessel in a laterally restricted channel may encounter a condition which tends to push the bow away from one side of the channel and draw the stern toward it. These effects can occur independently when a channel is restricted either laterally or vertically and unrestricted in the other direction.

There is, however, another problem associated with the water level drop caused by the presence and movement of a ship in restricted waters. This water level drop in the vicinity of the ship is in effect a trough which extends from the ship to the shore and which moves along the river or channel at the same velocity as the ship. As the ship's speed increases the moving trough deepens.

In the restricted channel sections of the St. Marys River, this effect might be most easily envisioned as a channel constriction. The conservation of energy principle applied to subcritical flow in an open channel as the flow passes through a channel construction indicates that the water surface will drop as the flow passes through the constricted portion of the channel.

The energy relation (neglecting losses) takes the form of:

$$\frac{V_1^2}{2g} + Y_1 = \frac{V_2^2}{2g} + Y_2$$

where V_1 and V_2 are the velocity and depth prior to the constriction, V_2 and Y_2 are velocity and depth within the constricted passage, and g is the acceleration due to gravity.

This is combined with the continuity relation:

$$Q = A_1V_1 = A_2V_2$$

where Q is the discharge and A_1 and A_2 are areas available for flow before and within the constriction, respectively. Before the above relation can be applied in the given form, the unsteady flow with the passage of a ship should be converted to steady flow by adding a velocity vector to the flow sections equal but opposite to the vessel speed.

The phenomenon of nearshore drawdown and surge during vessel passage may be explained in terms of the moving trough. In sufficiently deep water, the moving trough appears as a fluctuation in the elevation of the water surface. To an observer in a shallow or nearshore area where the depressed water level approaches or reaches the river bed, it appears that the water level recedes from the shoreline as the ship passes and that this is followed by an uprush and finally a return to normal level after the vessel-induced surface waves are dampened.

Using a simplified model where the system is converted to steady flow for analysis by conceptually stopping the ship and adding an opposite velocity vector to the flow, it is possible to initiate critical flow in the constricted area between ship and shore. Energy considerations would require the water level to rise in front of the ship before development of the trough should the ship's speed be increased beyond that required for the initiation of critical flow. An observer on the shore would then see the water level first rise before observing the effects of the moving trough.

Measurements and Observations

Water level measurements and directional water velocity measurements were made at a number of locations along the St. Marys River under differing conditions with the passage of ships. Some of this information is presented here to illustrate the above considerations.

To analyze the mechanics of sediment transport during vessel passage, two-dimensional near-bottom velocity measurements were made. An example of these measurements is presented in Figure 1 for a passage of the Cason J. Callaway at Six Mile Point on the St. Marys River. As shown in Figure 1, the point of observation was approximately 500 ft offshore in 10 ft of water, while the navigation track was another 700 ft offshore. The ambient downstream water velocity was approximately 0.3 ft/s. The direction of the near-bottom water movement rotated 360° during the passage of the Callaway with velocities in all directions significantly greater than the ambient downstream current.

Water level measurements and directional water velocity measurements have been made at a number of locations under various conditions with the passage of ships. A set of water level and velocity measurements is shown in Figure 2 which illustrates the trough effect near the shoreline and the complex velocity pattern which developed at an offshore point because of vessel passage. Velocity direction is indicated as an arrow at any particular point, with the magnitude of the velocity and time as the axes.

The velocity meter was located approximately 130 ft from the shore in 3 ft of water. The velocities shown were measured within 8 in. of the bottom. The water level gage was located near the shore in about 8 in. of water. The ship which caused the situation illustrated in Figure 2 was the J. Burton Ayers, moving upriver near Nine Mile Point on the St. marys River under ice-free conditions. The Ayers is 620 ft long, has a 60 ft beam with a midship draft of 23 ft. The vessel was traveling at 10.6 mph and passed approximately 800 ft from the shore.

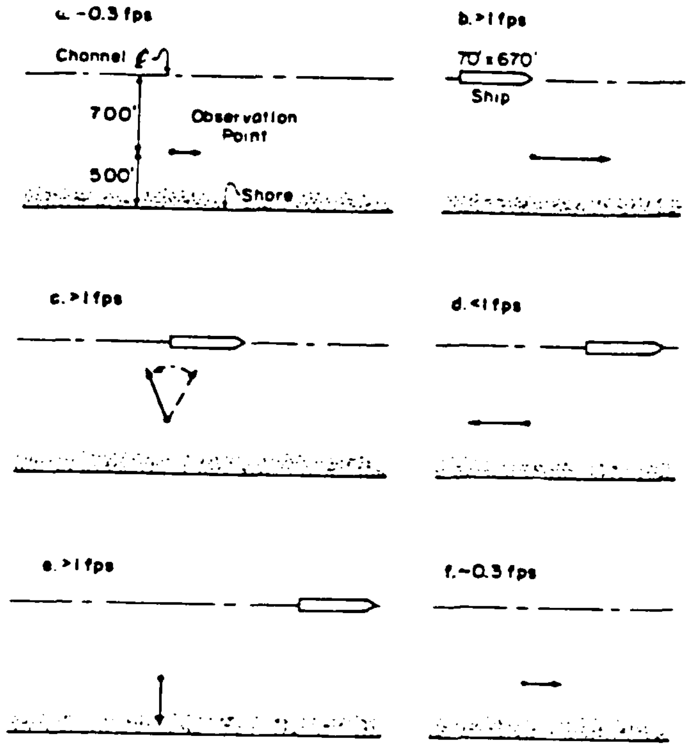

Figure 1. Ship-induced water movements.

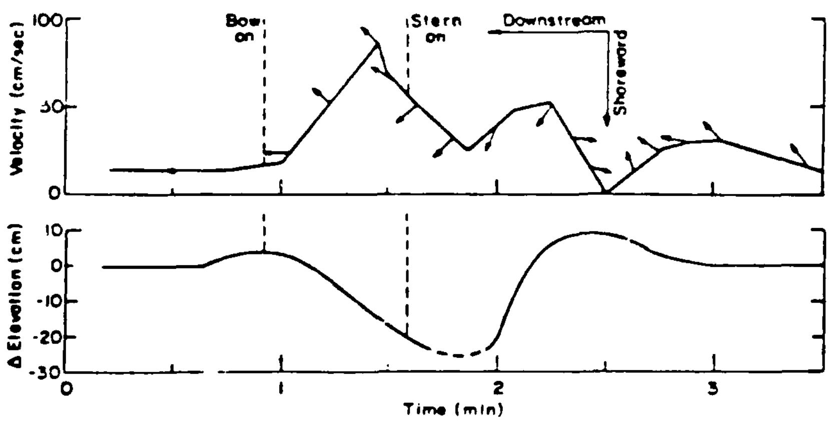

Figure 2. River level and near-bottom velocity pattern with upbound ship.

Figure 3 shows ice level changes at three offshore locations near Six Mile Point on the St. Marys River. The ice was approximately 15 in. thick. The ship passing the section was the Seaway Queen, moving upriver at 8.6 mph. The ship is 720 ft long, with a beam of 72 ft and a mid-ship draft of 17 ft, and passed 1000 ft offshore. The typical river cross section at this location is shown in Figure 4.

The two lower curves shown in Figure 3 illustrate ice level changes at two different locations on a line approximately normal to the direction of ship movement in different depths of water (labeled E_1 and E_2). The top curve (labeled H_1) shows the ice level change at a point 150 ft upstream on a line parallel to the line containing points E_1 and E_2. The time at which the bow and stern crossed the perpendicular range line (E or H) is indicated on each curve by dashed lines. The figure illustrates the trough effect in different depths of water at differing distances from shore, as well as the movement of the trough with the ship's passage. Note that the time displacement between E_1 and H corresponds to the distance between the two range lines divided by the ship's speed.

Figure 5 shows ice elevation changes (ice 11 in. thick) and the associated velocity pattern near the bottom as the Edward L. Ryerson passed downriver. The range line used (E) is the same as that described in Figure 3. The ice level and velocity pattern are measured at a location about 300 ft from the shore where the river depth is about 6 ft. The ship is 730 ft long, has a beam of 75 ft, a draft of approximately 26 ft, and was traveling at 7 mph about 1000 ft offshore. Figure 5 illustrates the ice level response to the moving trough and associated velocity pattern for a downbound vessel. Ice level fluctuations as large as 2.6 ft have been observed.

Shore Damage

The role of ice in sediment transport and shoreline erosion has many facets. The most obvious effect is that ice formed on a shore or riverbank may isolate and thereby protect the shore as shown in Figure 6. Ice formations can, however, cause significant localized damage by gouging ordinarily stable beach or bank formations, removing protective vegetation, by adfreezing sediment at the ice-soil interface, and by entrainment of sediment within the ice structure.

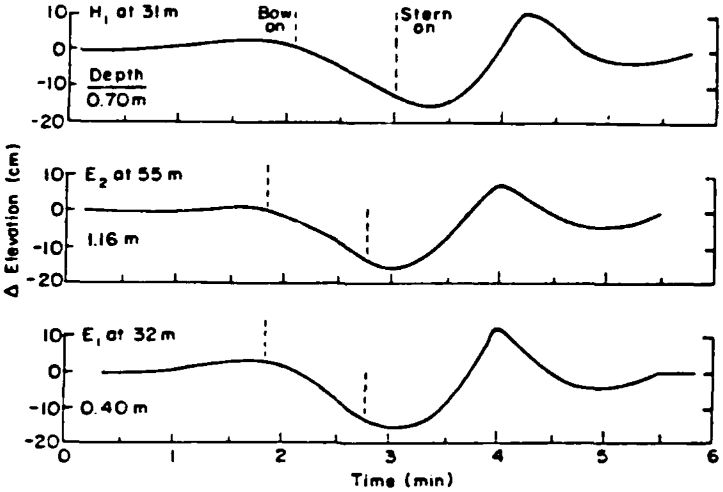

Figure 3. Ice level changes with upbound ship.

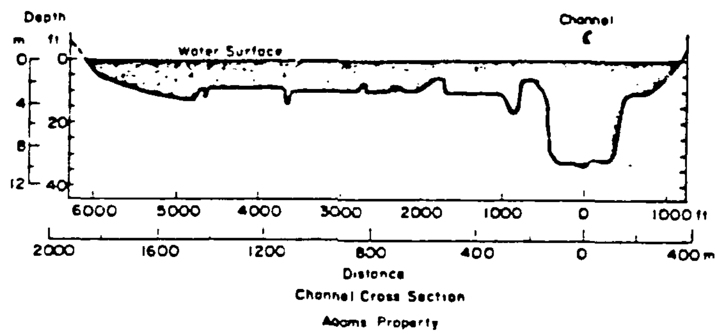

Figure 4. Cross section of the St. Marys River near Six Mile Point.

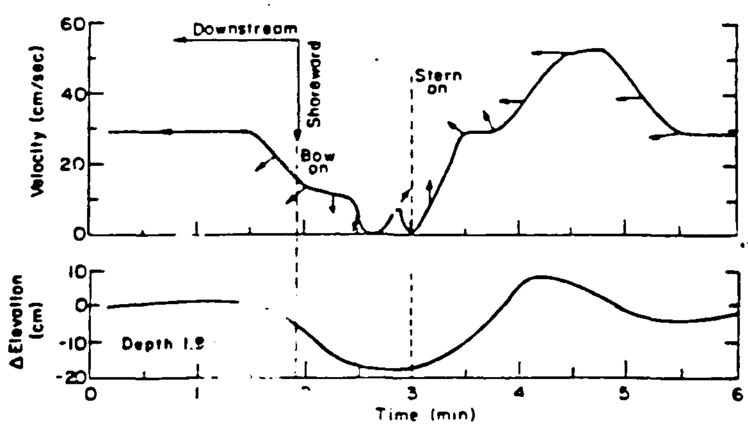

Figure 5. River level and near-bottom velocity pattern with downbound ship.

Figure 6. Early winter shore ice.

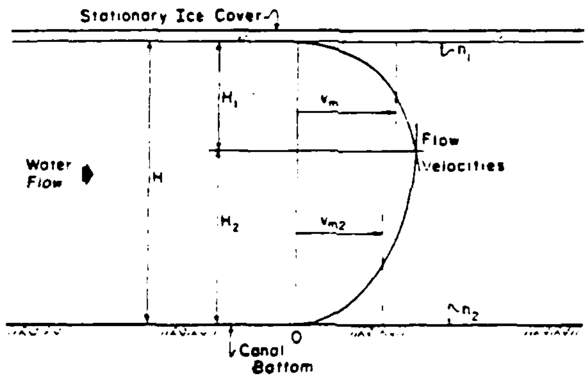

Figure 7. Theoretical velocity distribution in an ice-covered channel.

Another consideration is the effect of ice on the general hydraulics of a system. In a river, the presence of an ice cover changes the open channel conditions into a form of closed conduit flow with resultant changes in velocity profiles and distribution. As shown in Figure 7, the added boundary shear due to the ice cover will decrease flow velocities and increase flow depth. Although there may be anomolies, in general the presence of an ice cover will tend to reduce sediment discharge. The presence of ice jams, frazil dams or other ice irregularities causing a constriction or deflection of flow may result in damage.

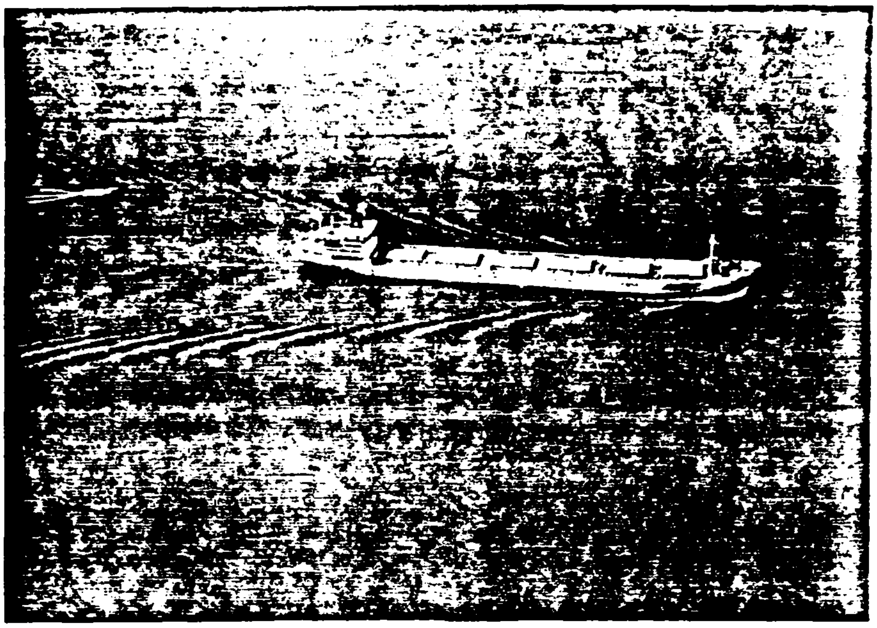

Figure 8. Wave patterns formed by ships in open water.

Shore damage due to the lateral movement of ice induced by vessel passage is ordinarily small, limited to early or unstable ice conditions, and shore areas in close proximity to the navigation track. During spring break-up larger, more massive ice floes may act upon a shore, but with warmer temperatures the ice is usually deteriorated and weaker.

Shore damage due to the horizontal movement of ice, while possible significant, is unpredictable, infrequent, and difficult to quantify. A long length of shoreline may be affected over a period of years, but only a small portion of such a reach might be affected in any one year. As a result, structural shore protection would be difficult to apply and most likely uneconomical. The regulation of vessel traffic in affected areas during certain ice conditions periods may provide the best means of damage mitigation.

Propeller wash, while sometimes a significant effect, is generally unaffected by the presence of ice. In addition, it is a fairly localized effect, and since this report deals primarily with nearshore effects it will not be considered here.

Wave action is the mode of action normally associated with ship-induced shoreline erosion. When water is deep compared to ship dimensions, a system of diverging and transverse waves develops. As shown in Figure 8, diverging waves are those which form the familiar "V" shaped wave pattern associated with ship passage, while transverse waves form a less noticeable wave train which follows a vessel and are oriented normal to the sailing line. The waves produced by large-scale navigation are generally much smaller and less damaging than those produced by recreational craft, particularly when vessel speed and distance to shore are considered. In addition, winter ice conditions tend to dampen out these waves.

Sediment Transport. In order for sediment transport to occur, near bottom water velocities sufficient to overcome a sediment particle's resistance to motion must exist. These water velocities may be due to ambient river conditions, wind driven waves, general turbulence, or ship-induced effects among others, and might be enhanced by channel configuration or ice irregularities. During vessel passage large and rapid changes in river velocity magnitude and direction can occur.

Three modes of transport of granular bottom sediments have been observed during both ice-covered and ice-free conditions. They are bed load, which is typified by a pattern of slowly migrating sand ripples on the river bed; saltation load, the movement of individual sand grains in a series of small arcs beginning and ending at the river bed; and a process which will simply be called explosive liquefaction.

Saltation transport has often been observed with the passage of large vessels. This can be explained by the ship-induced velocity increases, examples of which are shown in Figure 1 and 2.

In addition to these alterations in water flow velocity, the changes in water surface elevation during ship passage can occur more quickly than the pore pressure in the soil comprising the river bed can adjust. If the decreased water pressure on the river bed during the passage of the moving trough occurs faster than the change in soil pore pressure, a net uplift force on the soil near the surface may occur. After the trough passes and the water level rises the process is reversed and there is a net downward force on the river bed sediment. As the ship passage cycle is repeated this mechanism would tend to encourage a net offshore migration of sediment in addition to any transport due to water velocities alone.

On several occasions, explosive liquefaction has occurred with the passage of large, deeply loaded vessels at speeds higher than normal.

Explosive liquefaction of the bed has been observed by divers working in the surf zones of lakes and oceans and often may also be observed from shore as waves break near shore. In the presence of a reasonably horizontal velocity field, the action seems to occur in two steps. Initially the bed seems to expand upward somewhat. This is immediately followed by a dispersion into suspension of the uppermost part of the bed and a movement of the temporarily suspended mass in the water current. In the absence of a current, the bed simply quakes or expands and individual particles move upward. Bed equilibrium is rapidly reestablished by gravity forces.

Since the drawdown and surge mechanism usually sets up water velocities in opposite directions, their effects have a tendency to cancel. However, natural currents or a sloped bottom can act in conjunction with vessel effects causing a net sediment transport downstream or offshore towards the navigation channel.

Another sediment transport mechanism operates when material is carried out of a cell (or restricted area). Cells include small bays and the heads or tails of islands. In a small bay sediment in shallow water may be moved around a point of land or into deeper water where the vessel effect is not as pronounced, allowing the sediment to settle. This may be the cause of reported deepening of small bays. At the head or tail of an island or point of land, vessel effects may transport sediment around the point. The land then shields the sediment from further vessel effects.

During winter ice conditions, the passage of the moving trough can cause the grounding of an ice cover in shallow water and nearshore areas, and nearshore cracks in the ice may develop running roughly parallel to the water depth contours. With recurring moderate water level fluctuations, these hinge cracks do not completely refreeze and can provide an ice-movement relief mechanism. Continuing vertical and horizontal movement of the ice cover may cause the accumulation of ice debris (which resembles pressure ridges) at these active cracks. Depending upon the characteristics of crack formation, ice dams extending to the river bed may develop at the cracks (Fig. 9).

Other Effects: The mechanisms described above may have effects beyond shoreline erosion. Large areas of grounded ice, which result from the

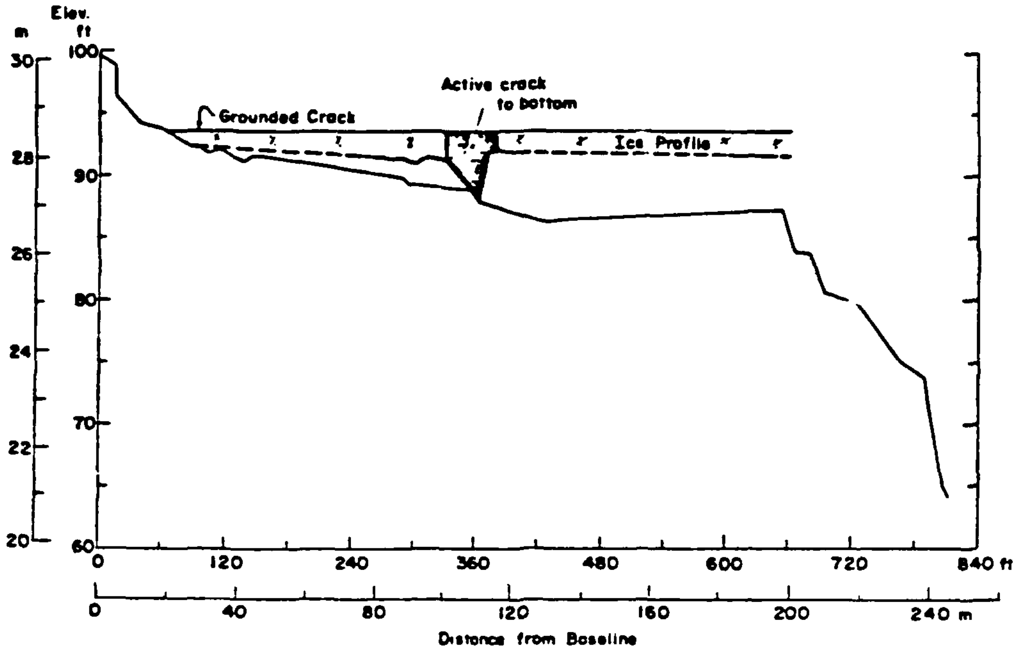

Figure 9. Active crack profile.

packing of brash ice under the ice cover, or increased frazil production because of increased open water areas may have an impact on benthic environments and may transmit ship induced vibrations to the shore and shore structures. The reported effects of these vibrations range from aesthetically disturbing to structurally damaging.

In wetlands or shoaling areas, damage may occur even though erosion is negligible. In shallow water, ship-induced velocity and water level changes could be large, possible disrupting vegetation by water and ice movement. An ice cover might even ground and directly strike the bed during vessel passage. Rapid water pressure changes might also be significant.

When a large enough, ship-induced moving trough passes through a shallow water area, the movement of bottom sediment may disrupt benthic environments, and the translatory movement of the water has been observed to cause water, sediment, vegetation, and even small fish to be sprayed up through the cracks and onto the ice. During a specific vessel passage, about a dozen fish of various species, ranging in size up to about 6 in. in length, were washed through a nearshore crack and onto the ice. It is possible that other, smaller organisms went unnoticed.

Structural Damage

Ice effects on structures typically fall into one of the following categories:

1) Static Ice Forces - These forces arise from an ice sheet in contact with a structure subject to thermal expansion and contraction or subject to steady wind or water drag forces.

2) Dynamic Ice Forces - These forces arise from ice sheets or floes which move against a structure due to water currents or wind.

3) Vertical Ice Forces - These forces arise due to a change in water level and require the adhesion of floating ice to structures.

For small structures in a river situation, such as the St. Marys River, the dynamic horizontal and vertical ice forces are typically the critical modes of ice action.

Horizontal Ice Forces: Depending on the size and strength of an ice floe, the horizontal force exerted on a structure may be dependent on the strength of the ice sheet and its failure mode (bending, crushing or shear) or by the magnitude of the force driving the ice sheet (wind or water current). With a vertical pile or structure face, failure of the ice sheet usually occurs by crushing. Current ASHTO standards employ a standard crushing strength for ice of 400 psi while the current Canadian bridge design code provides for "effective ice strength" values ranging from 100 to 400 psi. Thus if there is sufficient driving force for the ice sheet a pile subjected to horizontal ice loads would have to be strong indeed. Figures 10 and 11 show horizontal movement of thin sheets of early ice past some small docks and pile clusters while Figure 12 shows conditions during spring breakup where the moving ice floes are more massive. Figure 13 shows a small dock which has sustained damage due to horizontal motion.

Damage due to horizontal forces can occur naturally during the unstable early ice period or during spring breakup. Typically, during the mid-winter period on the St. Marys the ice is thick, and completely covers the water in most areas of the St. Marys River so that little horizontal movement takes place. With winter navigation, however, there can be small, incremental movement of large ice masses.

With the passage of a ship the resultant drawdown tends to draw water in the offshore direction. This also pulls the ice cover slightly toward

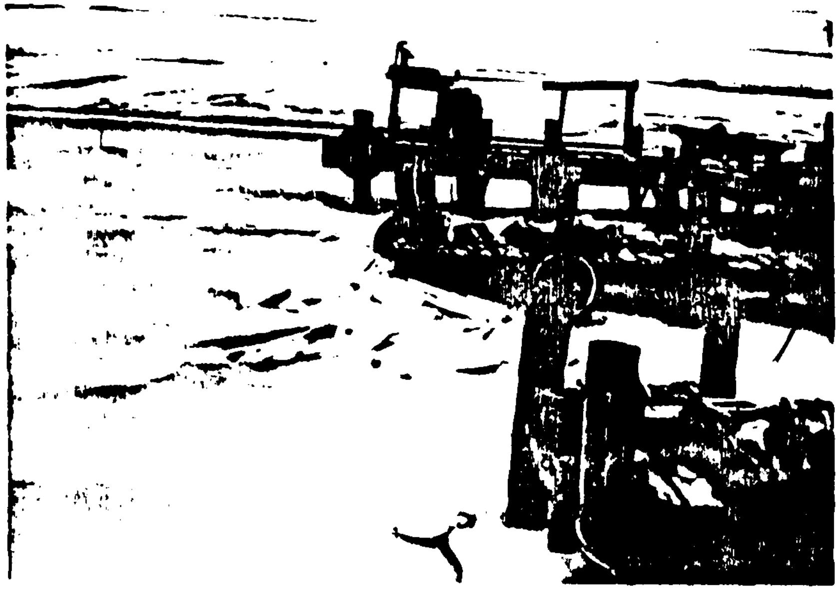

Figure 10. Horizontal ice movement against small dock.

Figure 11. Horizontal ice movement against pile cluster.

Figure 12. Ice conditions near Johnsons Point during spring breakup.

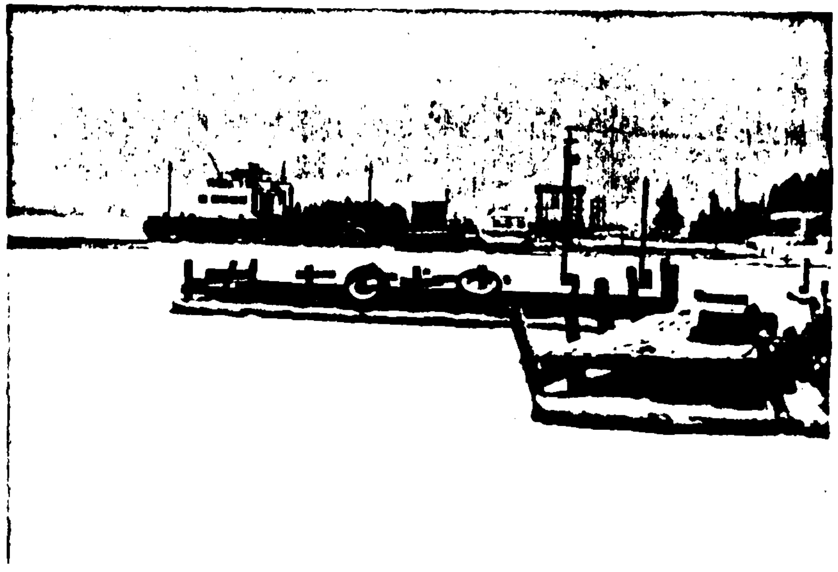

Figure 13. Small dock damage by horizontal ice forces.

Figure 14. Dock pulled offshore due to horizontal ice movement.

Figure 15. Dock attached to shore by cable to reduce movement.

the channel. The following rise in water levels does not completely close the crack, and there can be some freezing of new ice in the crack. With repeated cycles, this mechanism can incrementally jack the ice cover horizontally toward the channel. If any cracks pass through a structure they can be pulled offshore as well as shown in Figure 14. This has occurred so severely near Johnsons Point on the St. Marys River in the past that the owner of one dock structure has resorted to using wire rope cables to help protect his structures from being pulled offshore as shown in Figure 15.

Vertical Ice Forces: One source of damage is the vertical movement of an ice sheet. On any large body of water the water level is constantly fluctuating. Coastal variations are primarily due to tidal action, barometric pressure fluctions, wind set up, runoff and seiche action. During periods of open water, the normal fluctuations are relatively harmless. In conjunction with an ice sheet that is firmly attached to marine structures, these fluctuations can exert large vertical forces through the floating ice cover.

Typically the structures that suffer the most damage are light duty, pile supported piers such as those found on the St. Marys River for pleasure boaters. Designed for the summers activity, the support piles have very little skin resistance to an upward force. With a rise in water level, the buoyant ice sheet lifts the pile from the soil and the void under the bottom tip of the pile fills in. When the water level again drops, the weight of the ice is supported by the skin friction and point bearing of the pile. Since the pile is not driven into the soil as easily as it is pulled out, if the water level continues to drop, the ice will eventually break and the ice sheet will drop relative to the pile. The ice may then refreeze to the pile but at a lower position now that the pile has been lifted. This process then can be repeated in cycles throughout the winter, gradually "jacking" the pile completely out of the soil. Figure 16 shows a series of small finger piers whose piles have been jacked.

Typically for a pile when the temperature is below freezing the ice will adhere to a pile and break at some small distance away as shown in Figure 17. When temperatures are above freezing the ice may slip along a pile surface and even abrade the pile surface as shown by the wood shavings in Figure 18.

Another problem that may occur is when the water level is high enough so that the surface of the ice is in contact with the cross members of the dock as shown in Figure 19. Under this condition the ice forces now act directly on the structure.

With moderate water level fluctuations and sufficient cycle frequency, the crack in the ice sheet may not refreeze and a permanent open or "active crack" may result as shown in the air photo of Figure 20. This may serve

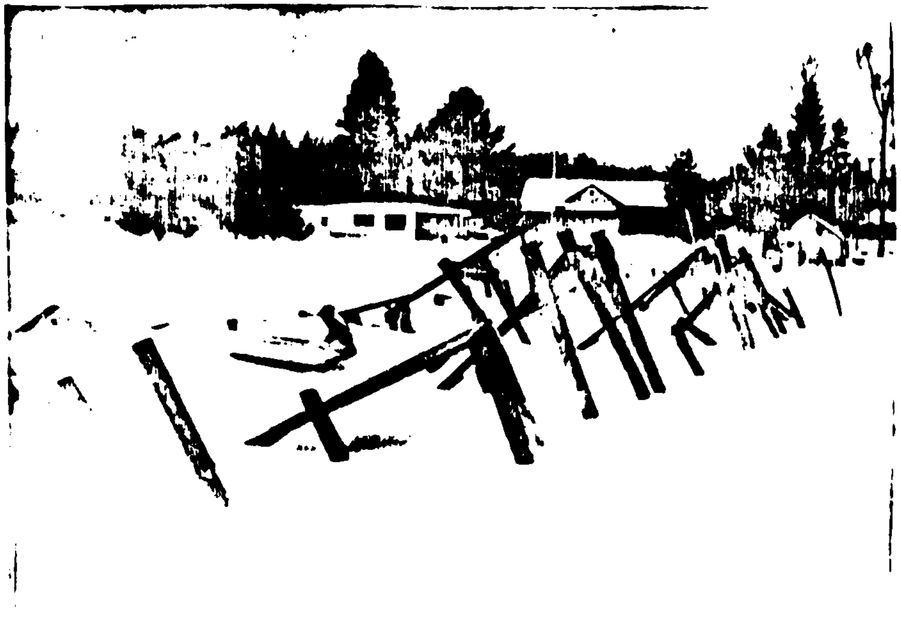

Figure 16. Series of finger piers damaged by ice jacking.

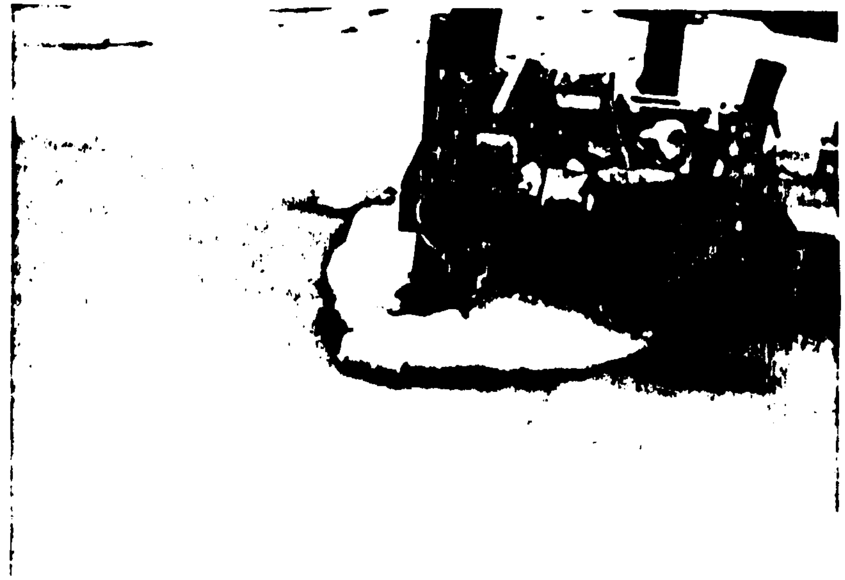

Figure 17. Ice collars on piles of small dock.

Figure 18. Abrasion of wooden pile by ice motion (note wood shavings).

Figure 19. Horizontal member of dock in contact with ice cover.

Figure 20. Active cracks near Johnsons Point.

Figure 21. Active crack passing through dock.

as a force release mechanism. Thus winter navigation, if the ships pass frequently enough and generate only small water level fluctuations (a few inches) may actually serve to reduce damage. If the crack passes through a dock as in Figure 21, if the ships pass infrequently so that the cracks may refreeze, or if the fluctuations are larger this protective mechanism is lost.

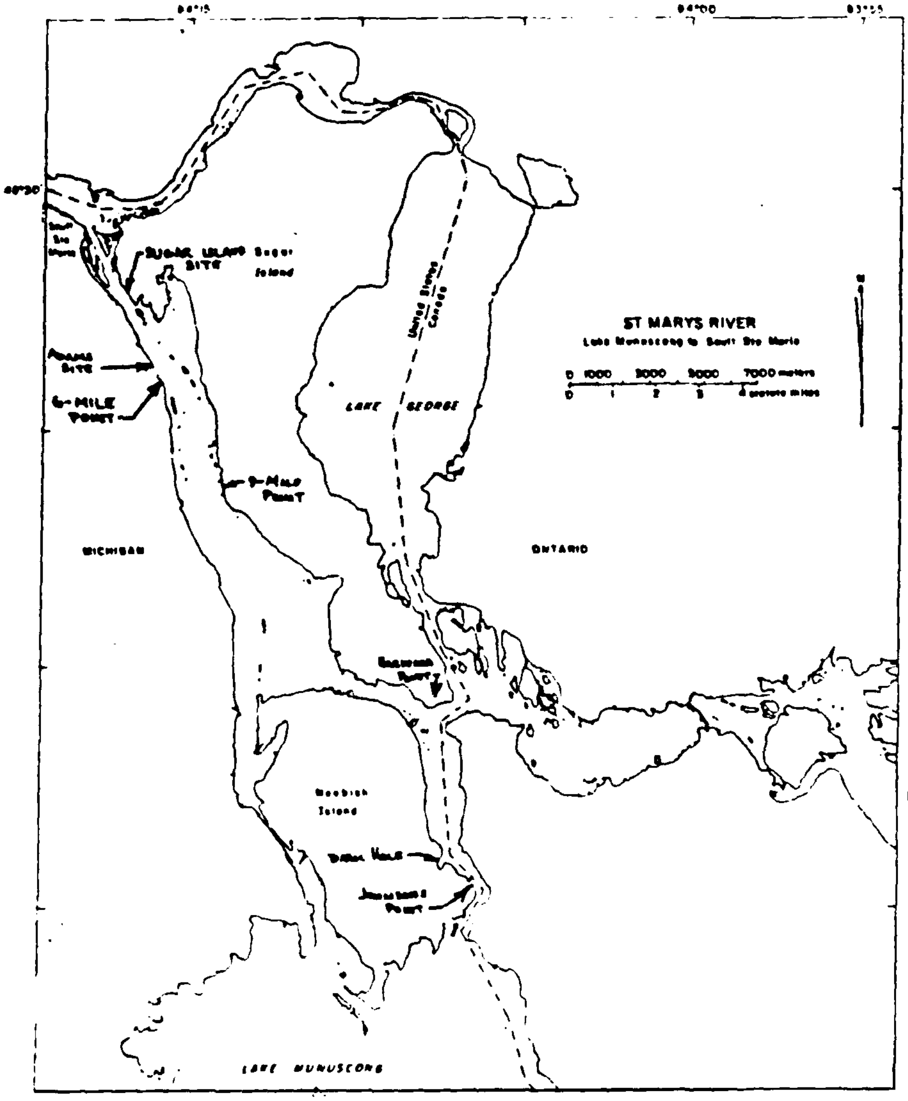

Figure 22. The St. Marys River.

If piles resist uplifting, they may generate a pile of ice rubble about them from the continuing water level fluctuations causing breaking of the ice about the pile. These rubble piles have been observed to develop to the point where they contact the horizontal members of a dock and cause damage.

OBSERVATIONS DURING THE 1980 CLOSED SEASON

The shorelines and shore structures along the St. Marys River were monitored for ice-related damage during the closed navigation season of 1980. This period extended from 15 January to 24 March with the only recorded vessel activity being seven trips by the USCG Katmai Bay and one trip by the USCG Mackinaw.

Sediment Transport and Shoreline Erosion

Various field measurements have been made by CRREL at sites along the St. marys River since 1976, and previous work was conducted by the Detroit District beginning in 1972. For the past field season three of these previously monitored sites were selected for further study during the closed navigation season. These sites are shown in Figure 22 and are referred to as the Sugar Island Site, the Adams Site and the Nine Mile Point Site.

A field data collection program was developed based on experience gained from work during previous winter navigation seasons. From past experience it was determined that measurements should include ice thickness profiles, river bottom profiles and locations and patterns of active cracks.

At each site, base and range lines had previously been established and are presented in Figures 23, 24, and 25. Range lines extend from each point shown on the baselines and extend normal to the baseline out into the river.

During periods of ice cover, holes were drilled through the ice at selected locations along several range lines and ice thickness and river bottom elevation were measured at these known locations. Any visible crack patterns were also noted during the periods of field measurements. River bottom elevations were determined by wading the range lines using conventional survey equipment after the spring breakup.

Ice Thickness Profiles and Active Cracks. Ice thickness measurements at the three sites are reported in Tables 1 through 8. The profiles were continued along the various ranges until it was considered to be unsafe for personnel to move further offshore.

In general, ice thickness tended to decrease offshore which is primarily due to the faster river currents present near the navigation channel. Also, while this was a study period of essentially no winter navigation there was still some limited ice-breaker activity from time to time during the winter of 79-80 and this caused some ice disruption in mid channel on occasion.

As noted within the Tables presenting ice thickness measurements there were no active cracks noted at the Adams site, only a grounded shore crack at the Sugar Island Site, and only on 1/31/80 was an active crack evident on one of the ranges at the Nine Mile Point Site. Such active cracks were

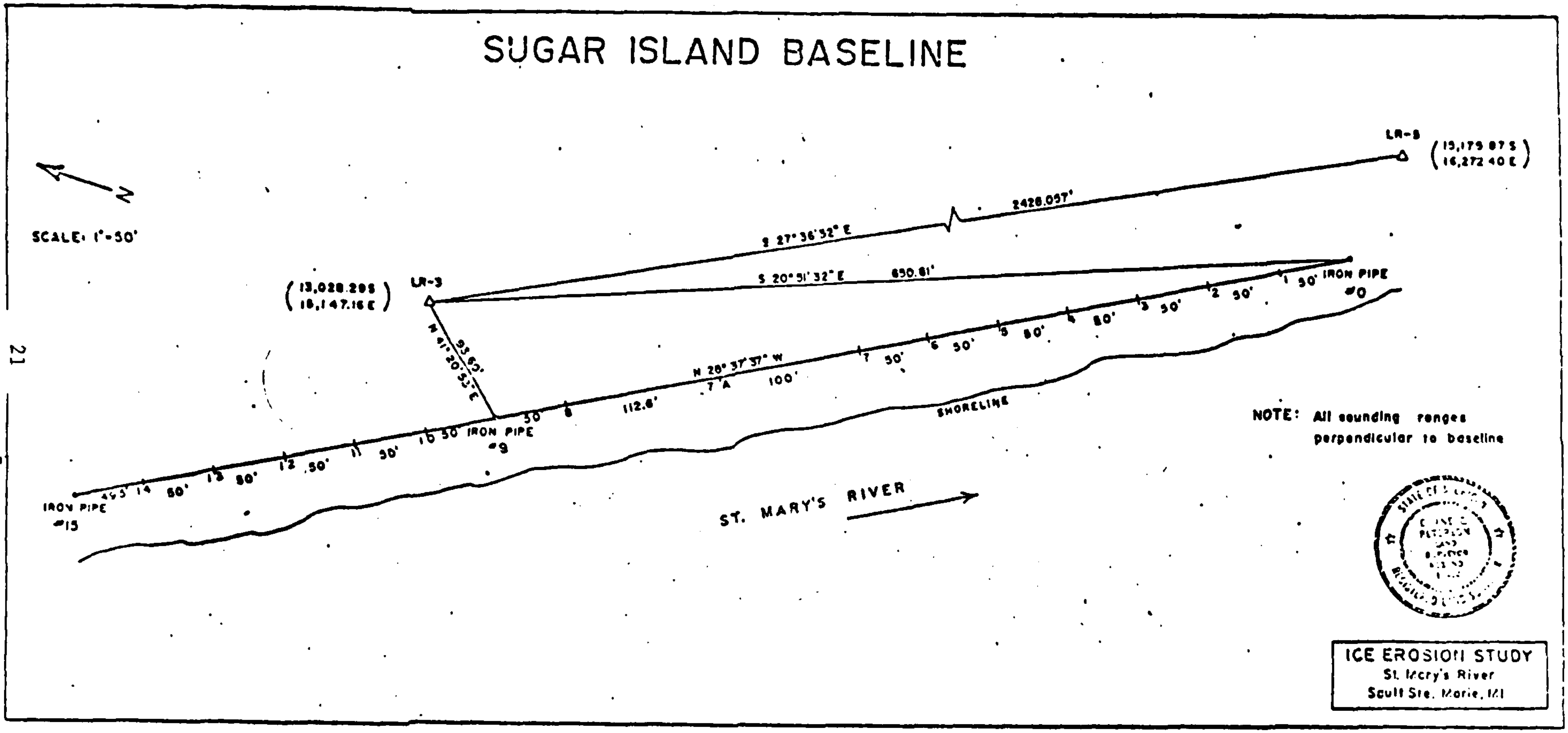

Figure 23. Sugar Island site layout.

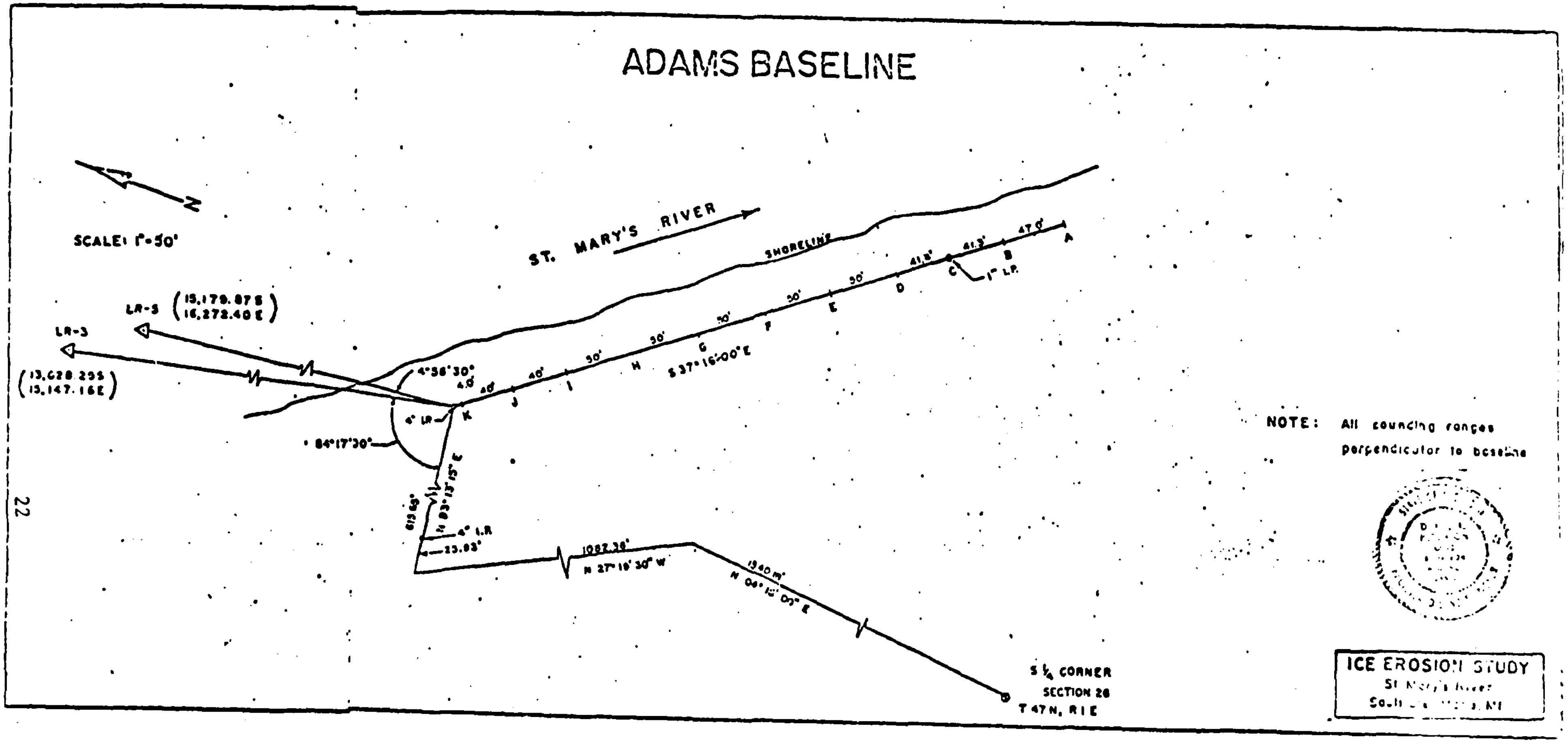

Figure 24. Adams site layout.

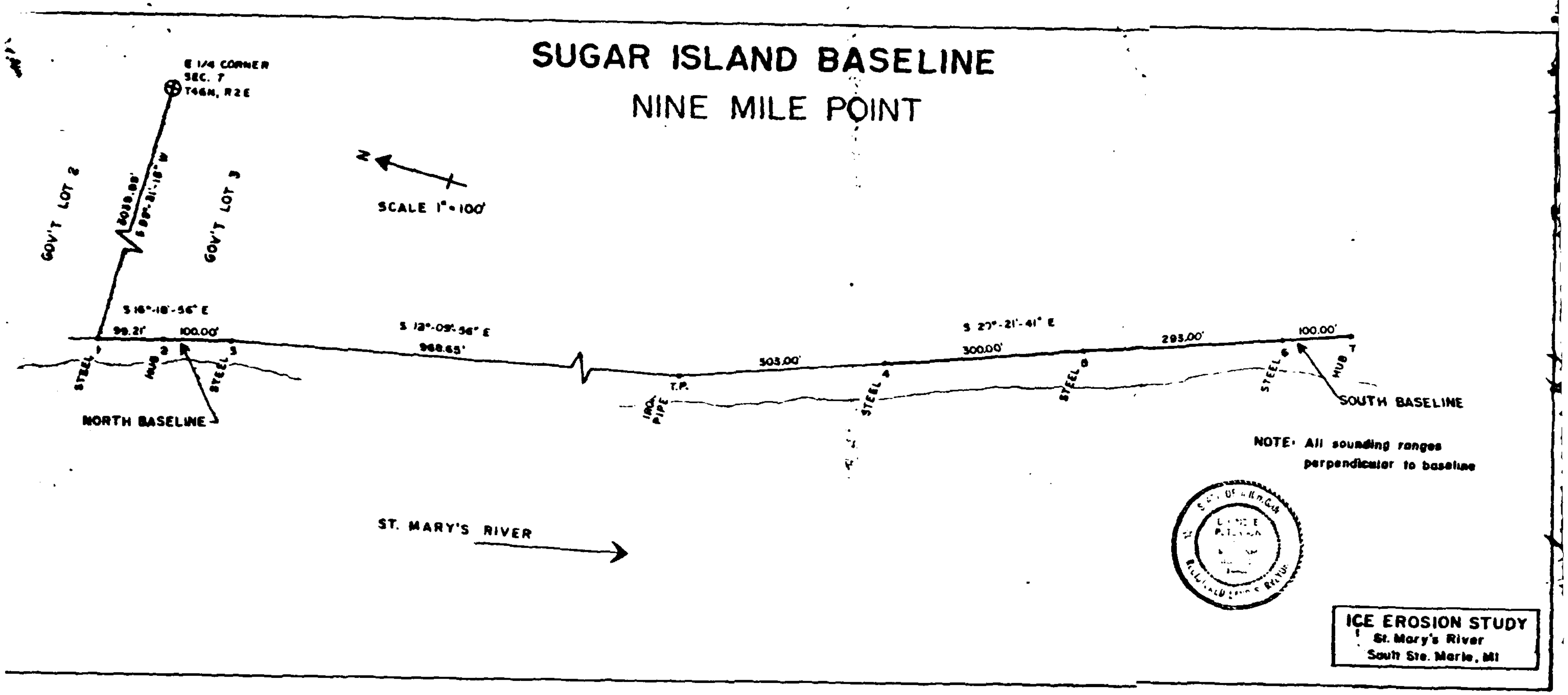

Figure 25. Nine Mile Point site layout.

TABLE 1 ICE THICKNESS AND CRACK PATTERNS AT ADAMS SITE

RANGE B

DATE	1/31/80	2/26/80	3/29/80
Distance (ft.)	Ice Thickness (ft.)	Ice Thickness (ft.)	Ice Thickness (ft.)
100	0.7	1.3	Fast grounded
150	0.7	1.2	shore ice to
160	0.7	1.2	a distance of
180	0.8	1.3	20 feet off-
200	0.7	1.2	shore.
220	0.9	1.3	Some drifting
240	0.9	1.3	pans offshore
260	0.9	1.1	of the fast
270	0.9	1.3	ice.
280	0.8	1.0	
290	0.9	1.2	
300	0.9	1.3	
320	0.9	1.0	
340	0.9	0.9	
360	0.7	0.8	
380	0.9	0.8	
400	---	0.6	
420	---	0.6	

(NOTE) No active parallel shore cracks - clear black ice - 2 inches snow on ice (1/31/80) - 6 inches snow on ice (2/26/80)

TABLE 2 ICE THICKNESS AND CRACK PATTERNS AT ADAMS SITE

RANGE E

DATE	1/31/80	2/26/80	3/29/80
Distance (ft.)	Ice Thickness (ft.)	Ice Thickness (ft.)	Ice Thickness (ft.)
200	0.8	1.3	Fast grounded
250	0.7	1.3	shore ice to
300	0.7	1.1	a distance of
310	0.8	1.2	20 feet off-
320	0.9	1.2	shore.
330	0.9	1.2	Some drifting
340	0.8	1.2	pans offshore
350	0.9	1.1	of the fast
400	0.9	1.0	ice.
450	0.9	0.9 (slush on ice)	
500	0.9	---	

(NOTE) No active parallel shore cracks - clear black ice - 2 inches snow on ice (1/31/80) - 6 inches snow on ice (2/26/80)

TABLE 3 ICE THICKNESS AND CRACK PATTERNS AT ADAMS SITE

RANGE J

DATE	1/31/80	2/26/80	3/29/80
Distance (ft.)	Ice Thickness (ft.)	Ice Thickness (ft.)	Ice Thickness (ft.)
200	0.9	1.3	Fast grounded
250	0.8	1.3	shore ice to
300	0.8	1.3	a distance of
320	0.9	1.2	20 feet off-
340	0.8	1.2	shore.
360	0.8	1.2	Some drifting
380	0.8	1.2	pans offshore
400	0.8	1.2	of the fast ice.
450	0.9	0.9 (slush on ice)	

(NOTE) No active parallel shore cracks - clear black ice - 2 inches snow on ice (1/31/80) - 6 inches snow on ice (2/26/80)

TABLE 4 ICE THICKNESS AND CRACK PATTERNS AT SUGAR ISLAND SITE

RANGE 0

DATE	2/1/80	2/26/80	3/29/80
Distance (ft.)	Ice Thickness (ft.)	Ice Thickness (ft.)	Ice Thickness (ft.)
100	0.8	open water	open water
200	0.8	to shore	to shore
250	0.8		
300	0.6 (some brash		
320	1.0 and snow ice)		
340	0.7 "		
360	0.8 "		
380	0.6 "		
400	0.7 "		

(Note) 2 inches snow on ice - no parallel cracks offshore - active parallel shore crack 20 feet out from base of bluff (2/1/80)

TABLE 5 ICE THICKNESS AND CRACK PATTERNS AT SUGAR ISLAND SITE

RANGE 7

DATE	2/1/80	2/26/80	3/29/80
Distance (ft.)	Ice Thickness (ft.)	Ice Thickness (ft.)	Ice Thickness (ft.)
100	0.8	open water	open water
150	0.8	to shore	to shore
200	0.8		
220	0.8		
240	0.4 (brash)		

(Note) 2 inches snow on ice - no parallel cracks offshore - active parallel shore crack 20 feet out from base of bluff (2/1/80)

TABLE 6 ICE THICKNESS AND CRACK PATTERNS AT SUGAR ISLAND SITE

RANGE 15

DATE	2/1/80	2/26/80	3/29/80
Distance (ft.)	Ice Thickness (ft.)	Ice Thickness (ft.)	Ice Thickness (ft.)
100	0.4	open water	open water
120	0.6	to shore	to shore
140	0.6		
160	0.8 (brash)		
--- unsafe			

(NOTE) 2 inches snow on ice - no parallel cracks offshore - active parallel shore crack 20 feet out from base of bluff (2/1/80)

TABLE 7 ICE THICKNESS AND CRACK PATTERNS AT NINE MILE SITE

RANGE 2

DATE	1/31/80	2/27/80	3/29/80
Distance (ft.)	Ice Thickness (ft.)	Ice Thickness (ft.)	Ice Thickness (ft.)
100	1.0	1.5	grounded shore
200	0.9	1.3	ice sheet for
300	1.0	1.3	a distance of
400	1.0	1.3	approximately
500	1.0	1.3	100 feet out
560	1.1	1.1	from shore.
580	0.9	1.1	
590	active crack	---	
600	0.8	0.8	

(NOTE) 2 inches snow on ice, evidence of snow covered broken pans along entire Nine Mile location (both ends) about 200 to 300 feet offshore 1/31/80 - No active cracks (2/27/80)

TABLE 8 ICE THICKNESS AND CRACK PATTERNS AT NINE MILE SITE

RANGE 7

DATE	1/31/80	2/27/80	3/29/80
Distance (ft.)	Ice Thickness (ft.)	Ice Thickness (ft.)	Ice Thickness (ft.)
100	1.3	1.9	Grounded shore
150	1.1	1.6	ice sheet for
200	1.0	1.5	a distance of
220	1.0	1.6	approximately
240	1.0	1.4	100 feet out
260	1.0	1.4	from shore.
280	1.1	1.4	
300	1.0	1.4	
370	1.0	1.3	

(NOTE) 2 inches snow on ice, evidence of snow covered broken pans along entire Nine Mile location (both ends) about 200 to 300 feet offshore (1/31/80) - No active cracks(2/27/80) commonly reported at all sites during previous years with winter navigation.

Offshore Bottom Profiles. Offshore bottom profiles were obtained at the locations noted for ice thickness measurements in Tables 1 through 8. These bottom elevations were compared with those previously reported for the earlier studies and no change was noted considering the accuracy of the measuring technique.

Near Shore Bank and Bottom Profiles. These profiles were measured in May of 1980 by wading using conventional survey equipment. The profiles were measured along all ranges at each of the three sites.

The profiles measured at the Adams Site were compared with profiles reported in the earlier studies. A previous report indicated some changes at Ranges I, J, and K due to local construction. The measurements made this season showed no further alteration of these three profiles nor any changes in any f the other range profiles. It would appear considering the history of these measurements that no serious erosion is occurring at this site.

Nearshore profiles at the Sugar Island Site are reported in Figures 26 through 31 and all fifteen ranges located at this site. Bank and bluff recession is evident at all of the range locations. This site has been active in the past periods of study which might have led to suspicions of the effects due to winter navigation, however, these nearshore alterations appear to continue during a period with essentially no winter navigation.

Profiles measured under this contract at the Nine Mile Point Site were compared with those reported in previous study periods. The profile measurements reported for earlier years have shown no change except for the inshore migration of a small berm near Range 5. The results of this study, however, showed nearshore alterations at all ranges except Range 3. These profiles are illustrated on Figures 32 through 38. Range 3 is protected with rip-rap and rock placed along the bluff and shoreline and no material nearshore alteration would be expected along this range. Ranges 1, 2, 4, 6, and 7 all show some recession of the shore area while Range 5 indicates some filling due to the migration of the sand berm located near this range. Water levels were high during the summer of 1979 and erosive forces would have been applied at higher elevations of the shore and bluff during this period.

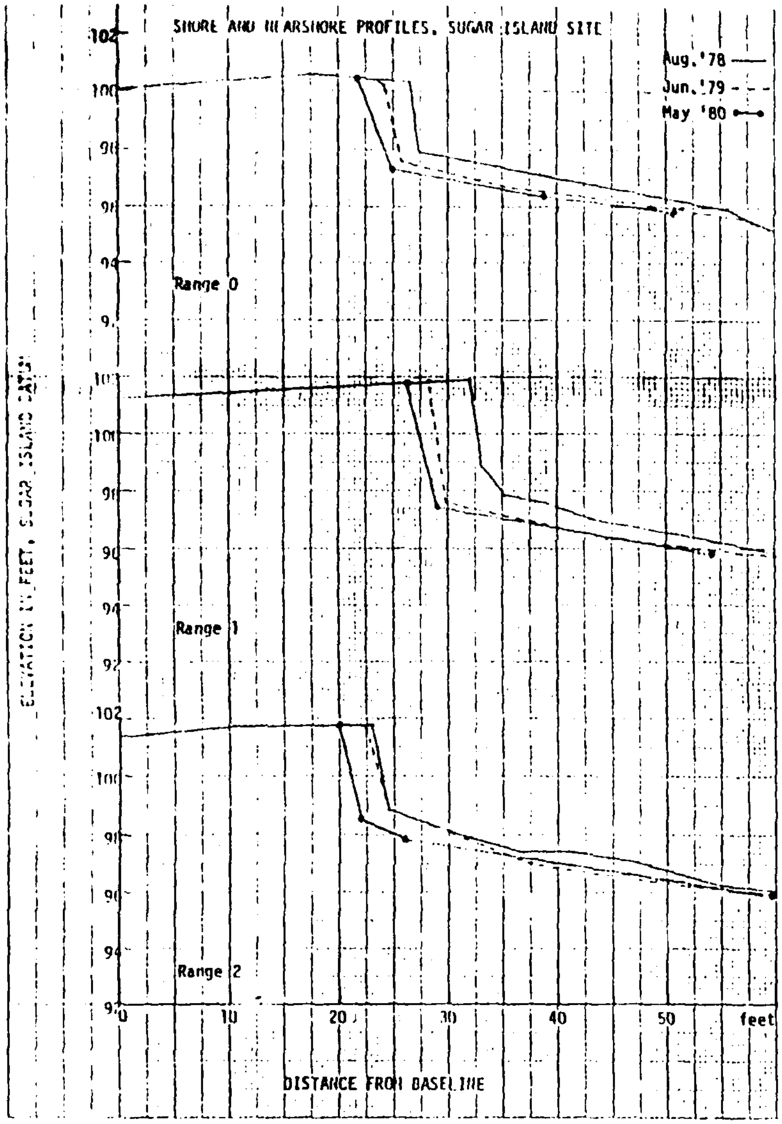

Figure 26. Shore profiles, Sugar Island site.

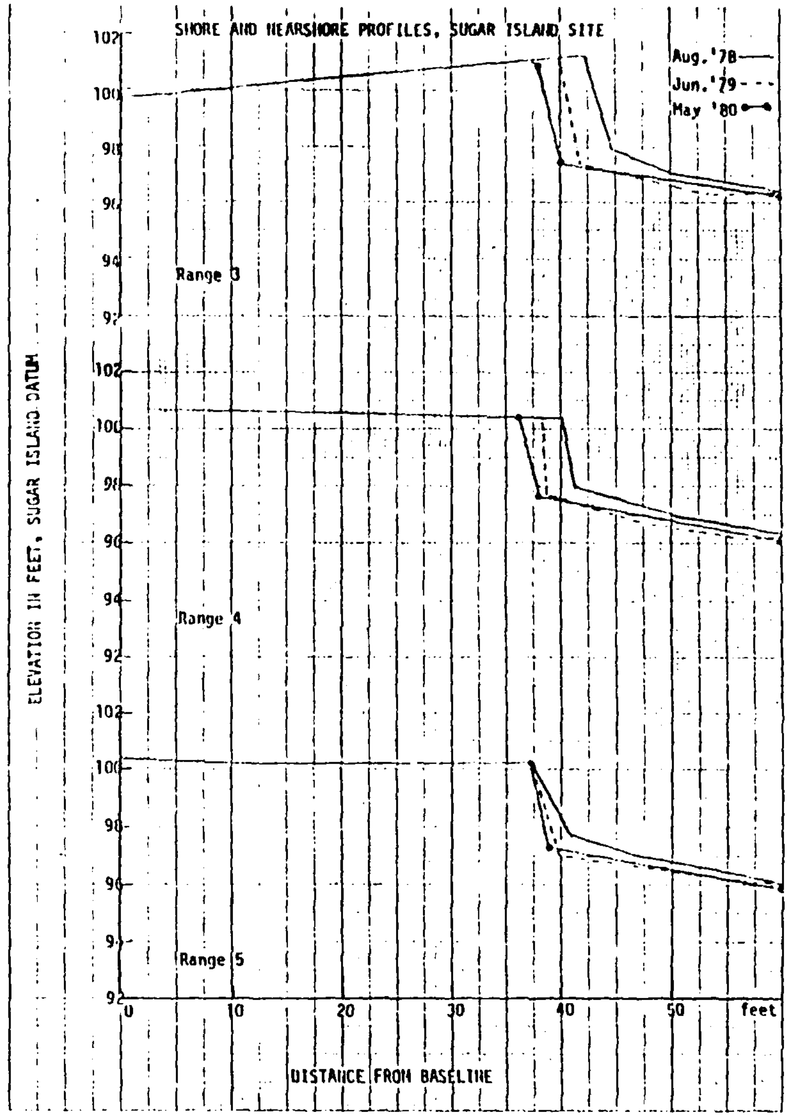

Figure 27. Shore profiles, Sugar Island site.

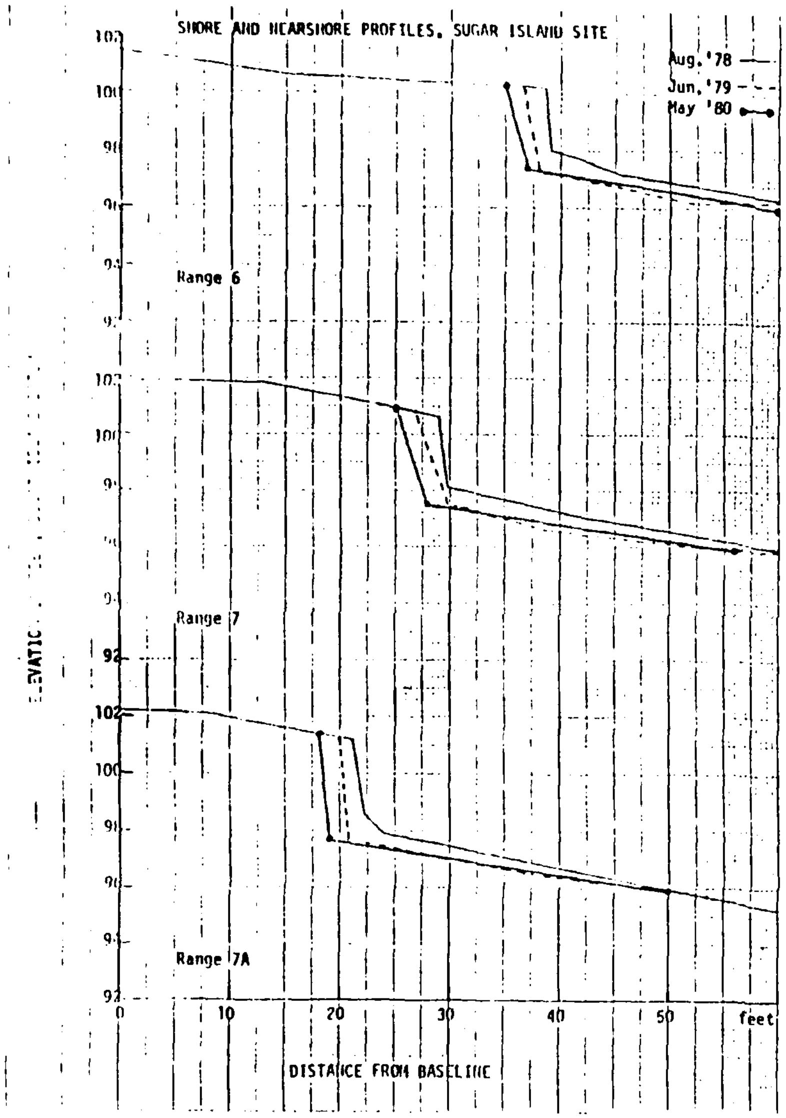

Figure 28. Shore profiles, Sugar Island site.

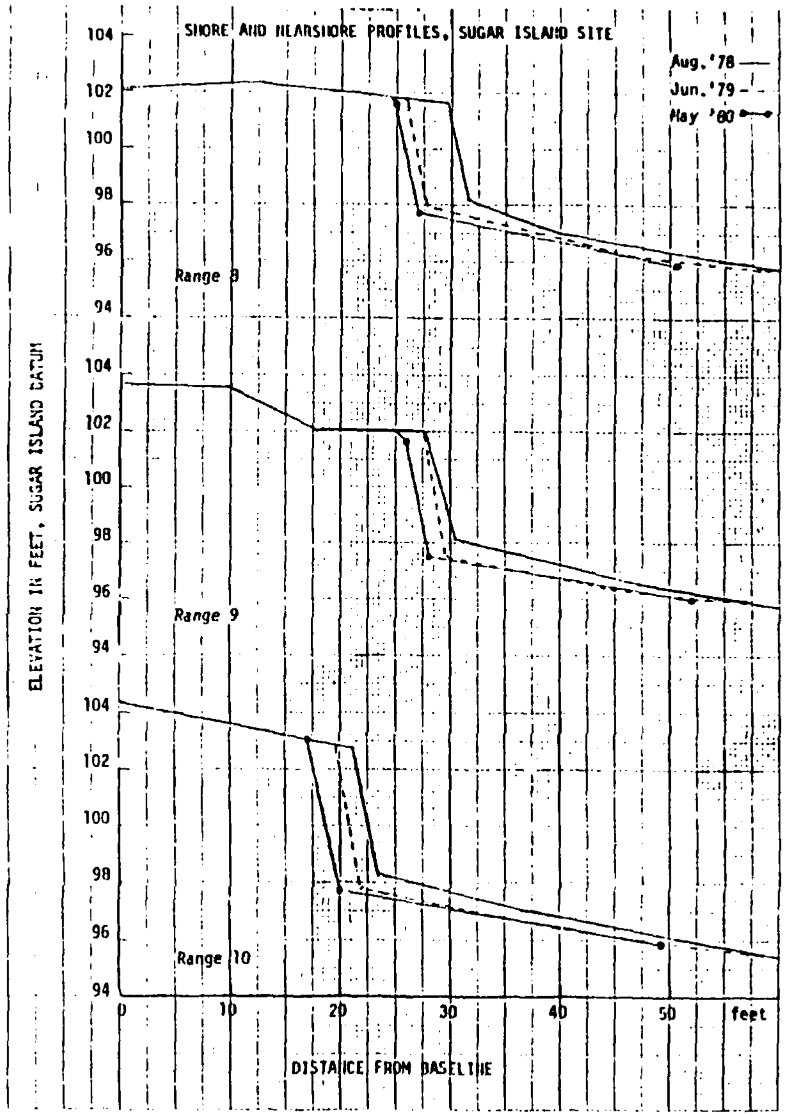

Figure 29. Shore profiles, Sugar Island site.

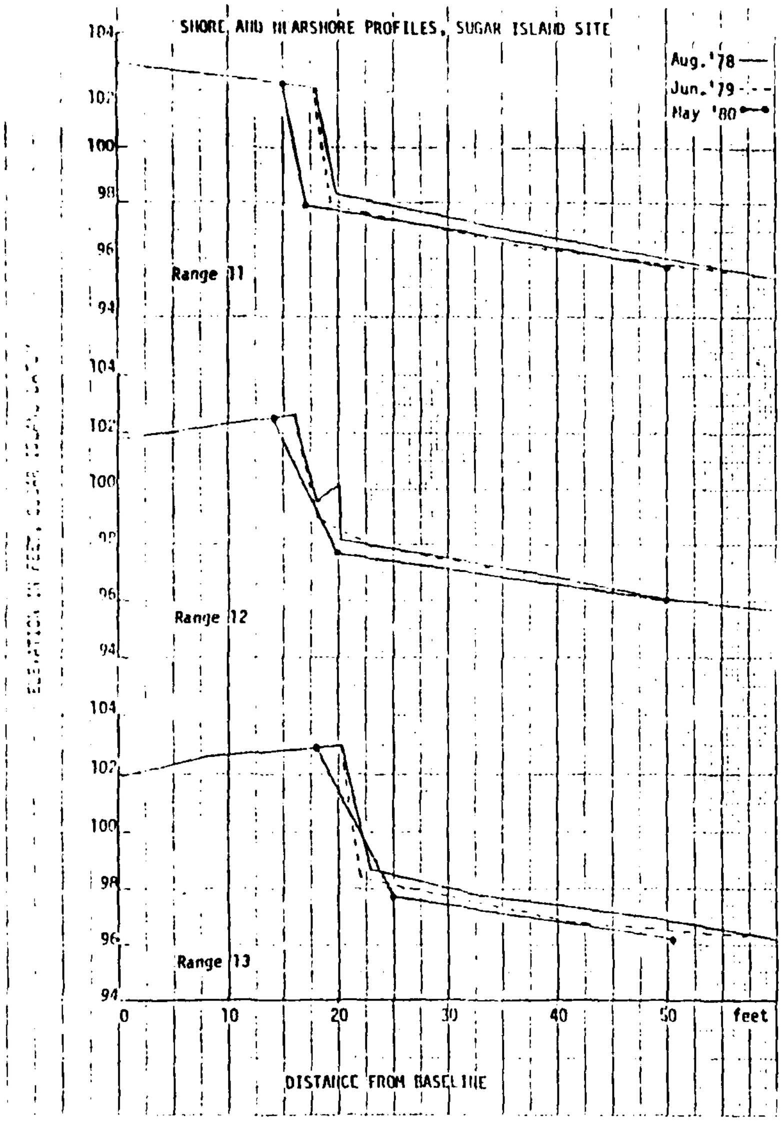

Figure 30. Shore profiles, Sugar Island site.

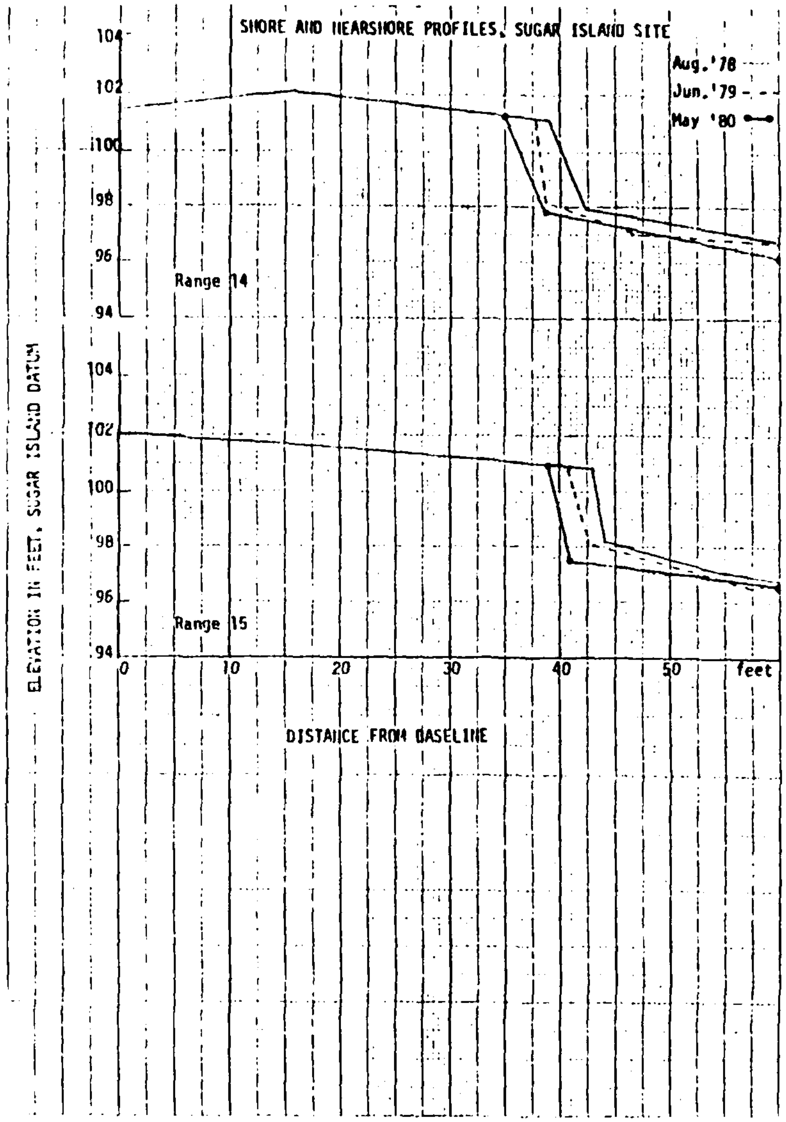

Figure 31. Shore profiles, Sugar Island site.

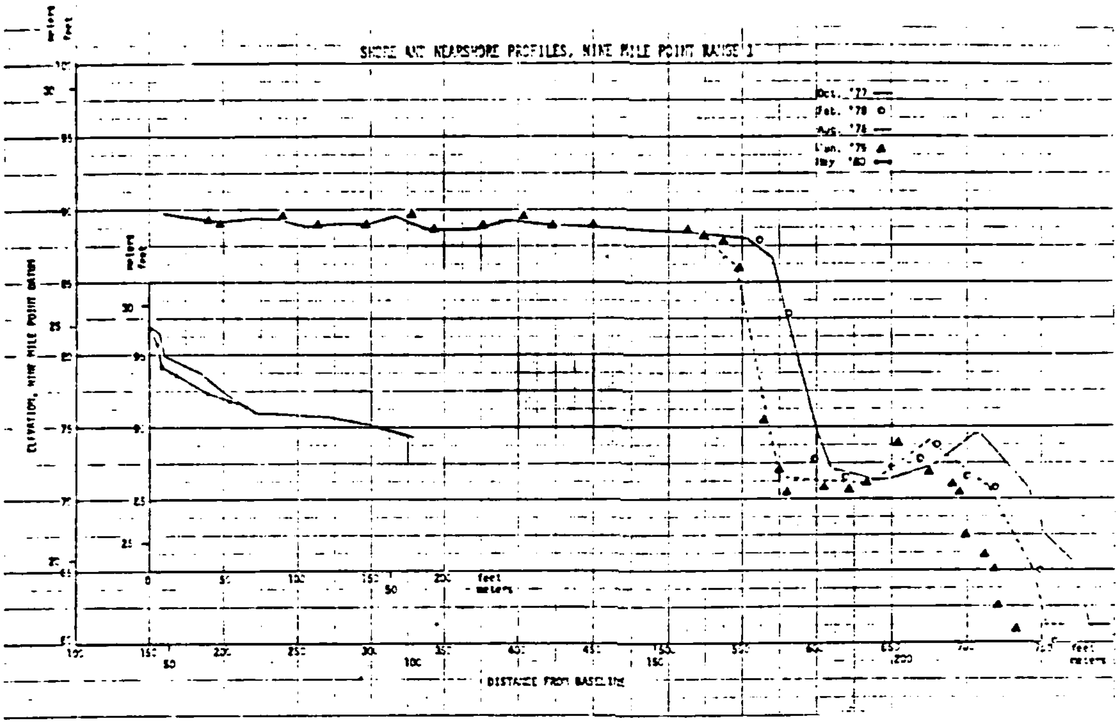

Figure 32. Shore profiles, Nine Mile Point.

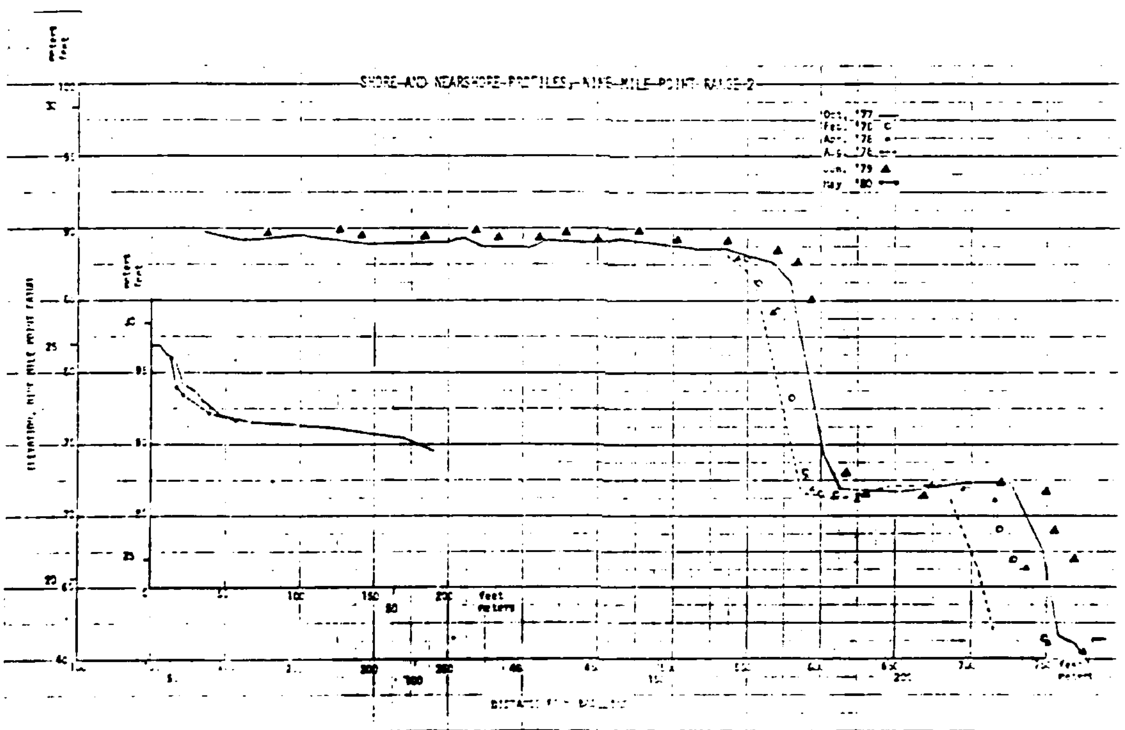

Figure 33. Shore profiles, Nine Mile Point.

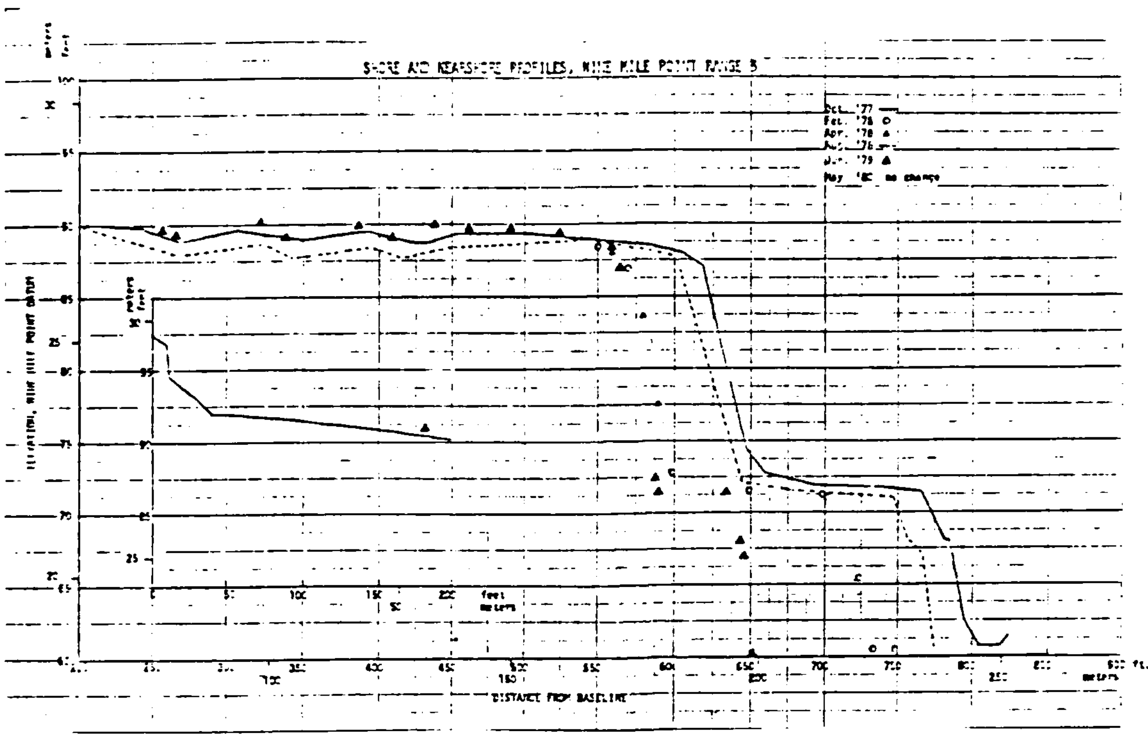

Figure 34. Shore profiles, Nine Mile Point.

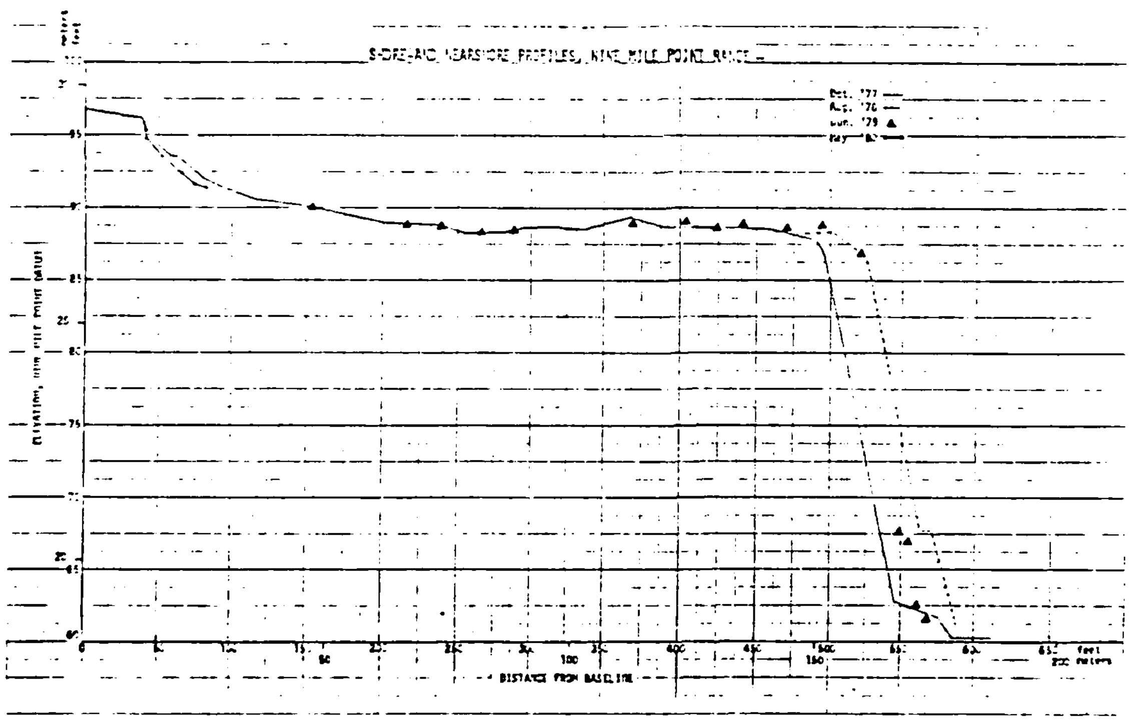

Figure 35. Shore profiles, Nine Mile Point.

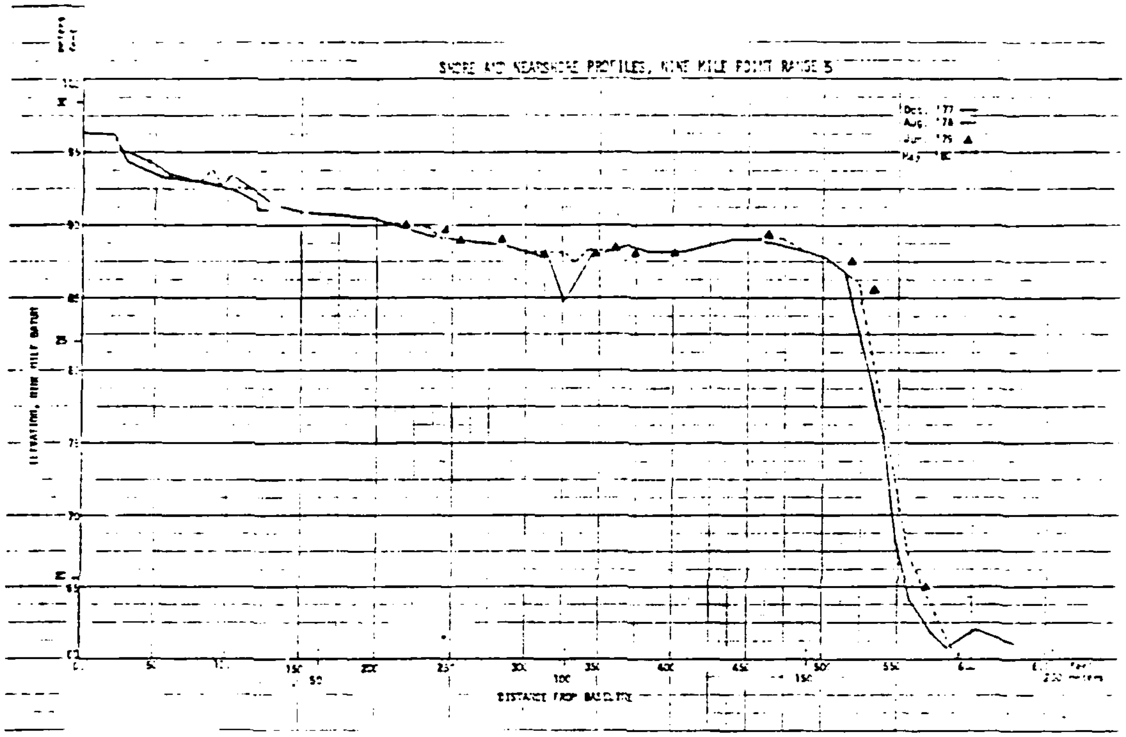

Figure 36. Shore profiles, Nine Mile Point.

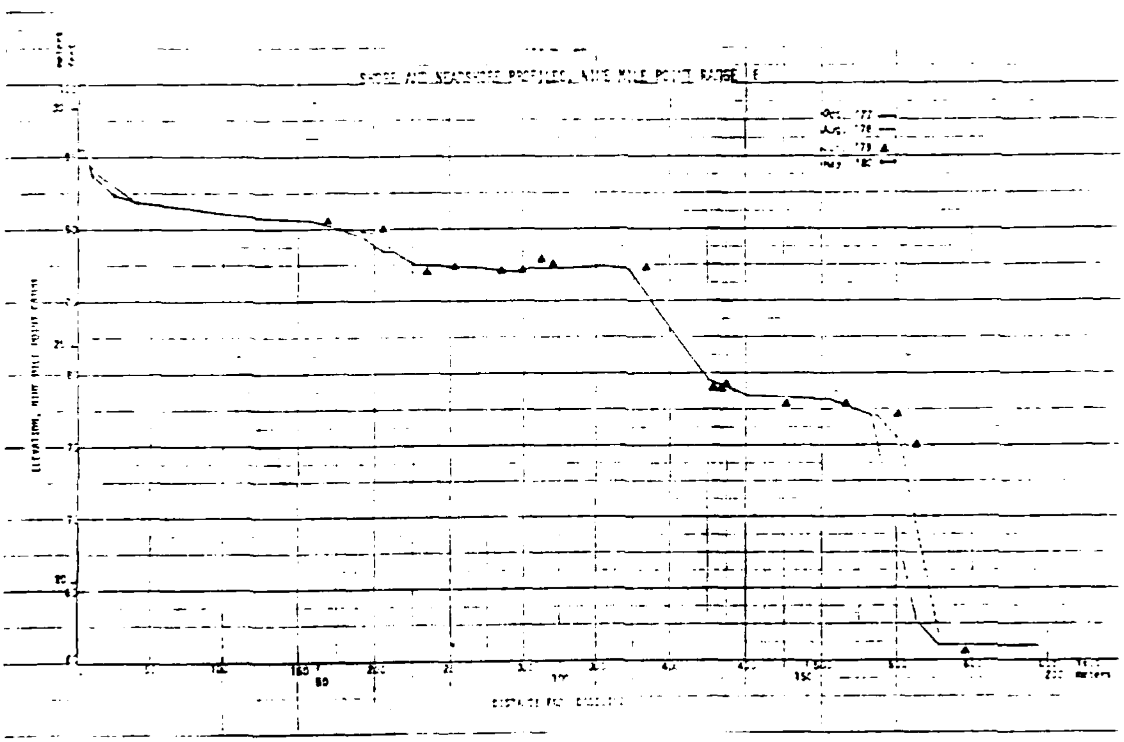

Figure 37. Shore profiles, Nine Mile Point.

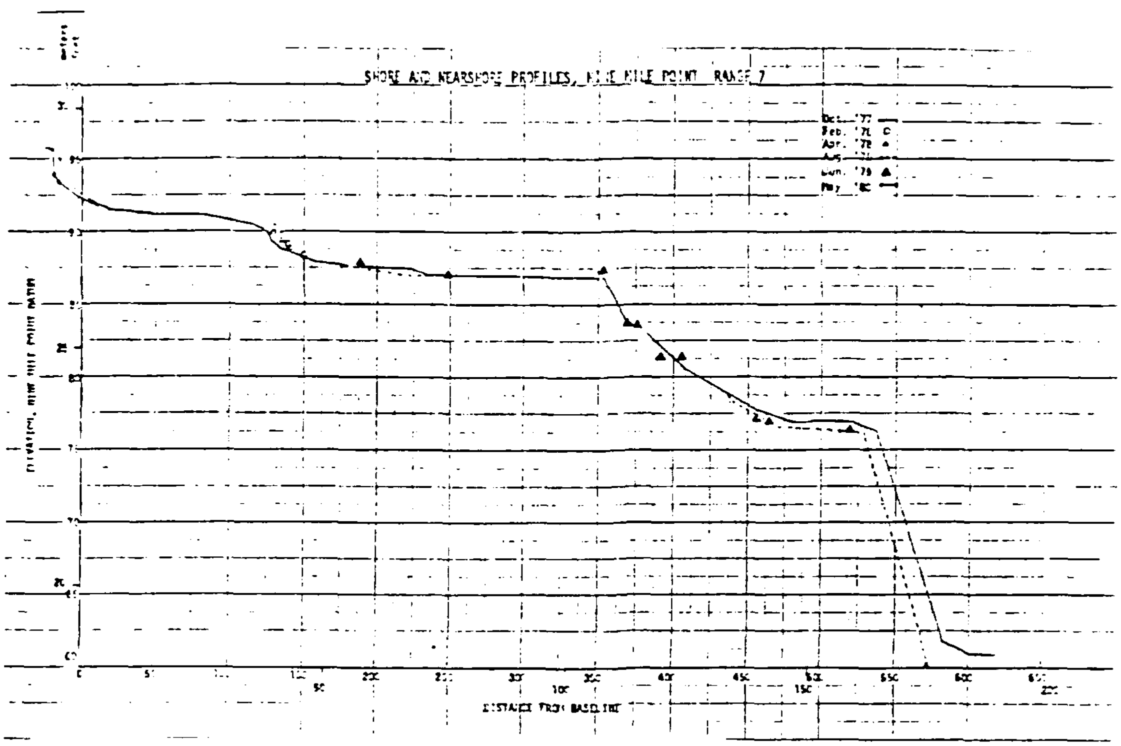

Figure 38. Shore profiles, Nine Mile Point.

It is interesting to note here that no material nearshore recession has been reported in the earlier years of study with winter navigation present while some recession did occur during this period of no winter navigation.

Dock Damage

Docks along the entire length of the St. Marys River were observed for ice-related damage. Emphasis was placed on structures in areas which have a high potential for damage or which have suffered significant damage in the past.

Docks were first visited just after the close of navigation, and some damage was evident due to both horizontal and vertical ice forces. Since the study was to address damage during a period without navigation, the condition of the structures during this first field period were used as a basis for future comparisons.

Six Mile Point. Structures at Six Mile Point are in an area of significant damage potential due to navigation, but they are better constructed than most along the St. Marys River. The docks at LaPeers Marine Gulf Station consist of a main dock extending perpendicular to the shoreline

Figure 39. Dock at Six Mile Point.

with a series of eight finger piers extending from it parallel to the shore. This structure is then surrounded by 12 pile clusters as shown in Figure 39. This photograph is from a previous winter and shown the rubble piles which develop about the pile clusters during a period with navigation.

Figure 40 and 41 were taken on 11 January 1980 just after the cessation of navigation. Figure 40 shows the active crack which can develop between the pile clusters at this site which then isolates the docks from vertical forces due to water level fluctuations. Figure 41 shows some ice rubble due to horizontal movement of a thin, early ice sheet. Thus pile clusters can help to protect a dock against both horizontal and vertical movements of the ice sheet. As shown in Figure 42, a change in water levels will still influence the ice about the dock, but the effective area of the ice which develops the vertical force on the dock is smaller and the group action reduces the uplift force on any single pile. With thin ice or

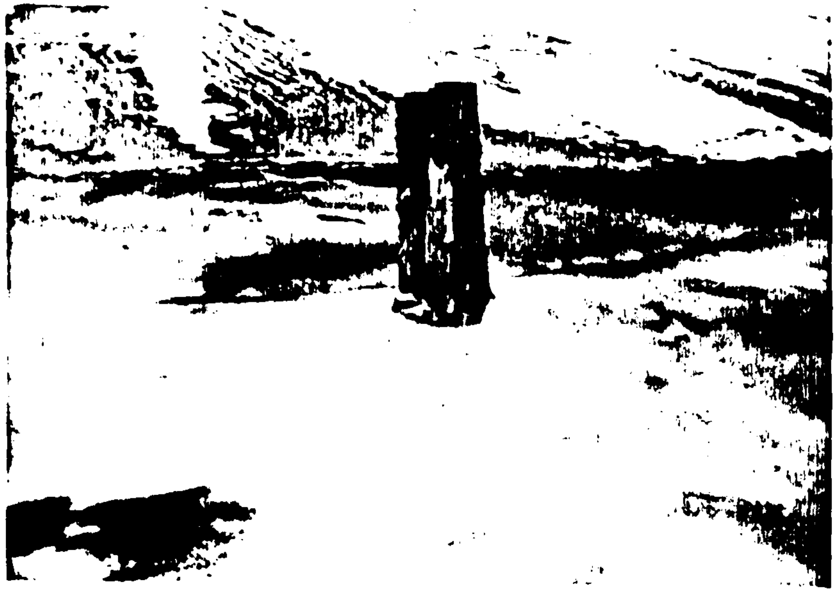
Figure 40. Active crack at pile cluster.


Figure 41. Ice rubble due to horizontal ice movement.

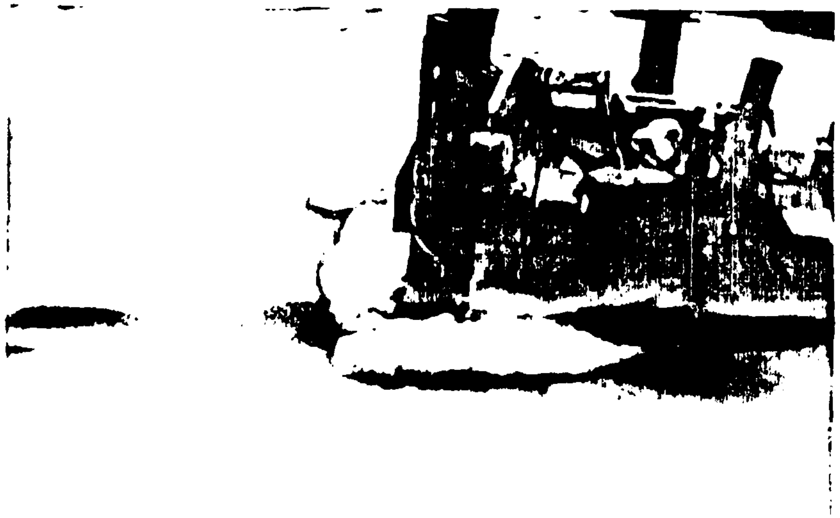
Figure 42. Ice collar on small dock piles.

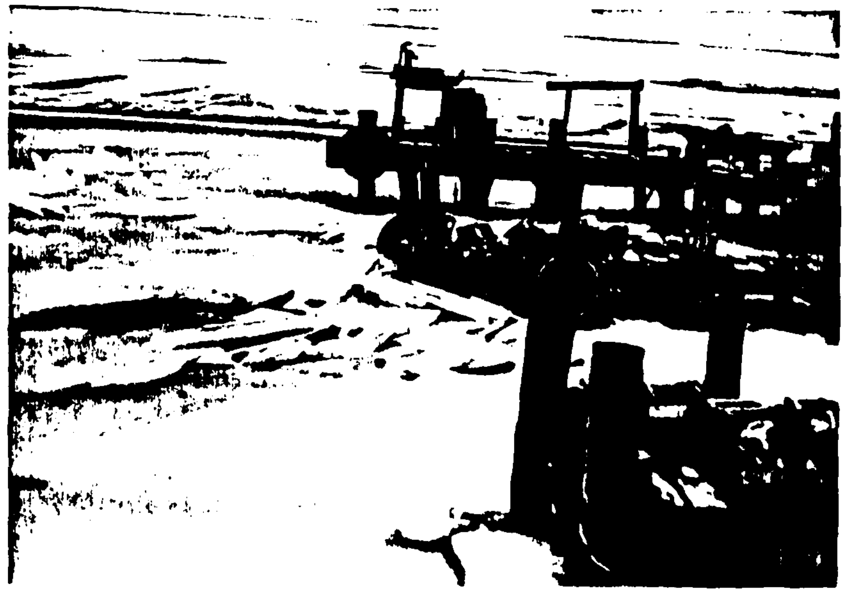
Figure 43. Horizontal movement of ice against dock.

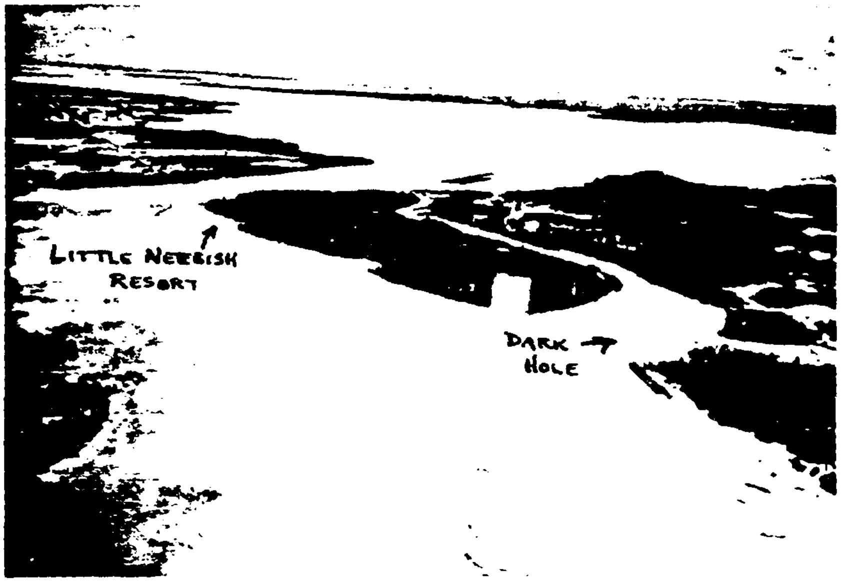

Figure 44. St. Marys River near Johnsons Point.

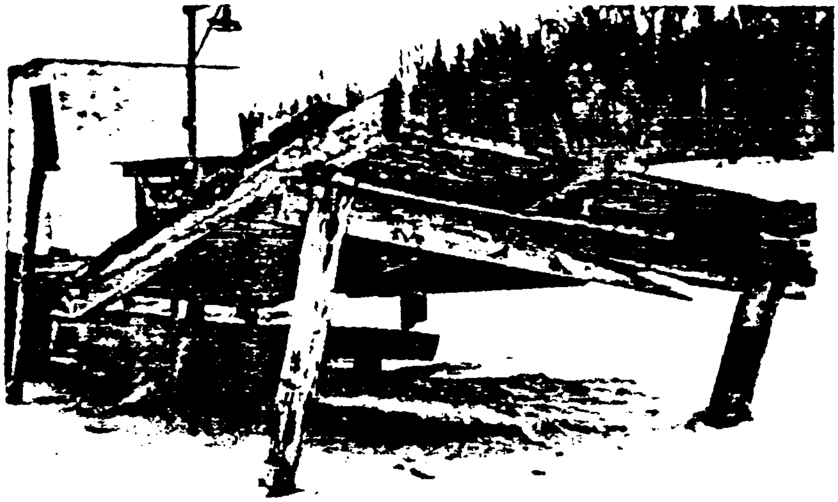

Figure 45. Franklin Resort dock, end view.

small floes, ice may still move horizontally against a dock, as shown in Figure 43, but due to the limited size forces are reduced.

The docks at Six Mile Point were monitored throughout the closed navigation season and no perceptible damage was observed.

Dark Hole, Neebish Island. Another site monitored during the closed navigation season was the area known as the Dark Hole on Neebish Island which is shown in Figure 44. during previous years the Franklin Resort

Figure 46. Franklin Resort dock, side view.

Figure 47. Dark Hole timber crib.

dock structure suffered significant damage due to uplifting forces as shown in Figures 45 and 46 taken during the 1976-1977 winter season.

Prior to the 1978-79 winter navigation season, the Corps of Engineers had two demonstration docks installed at this site. One was a rock-filled timber crib as shown in Figures 47 and 48. The other shown in Figure 49 was a pile supported structure, with pile surfaces of various materials ranging from wood to plastic to steel. Both of these structures stood up

Figure 48. Timber crib close up.

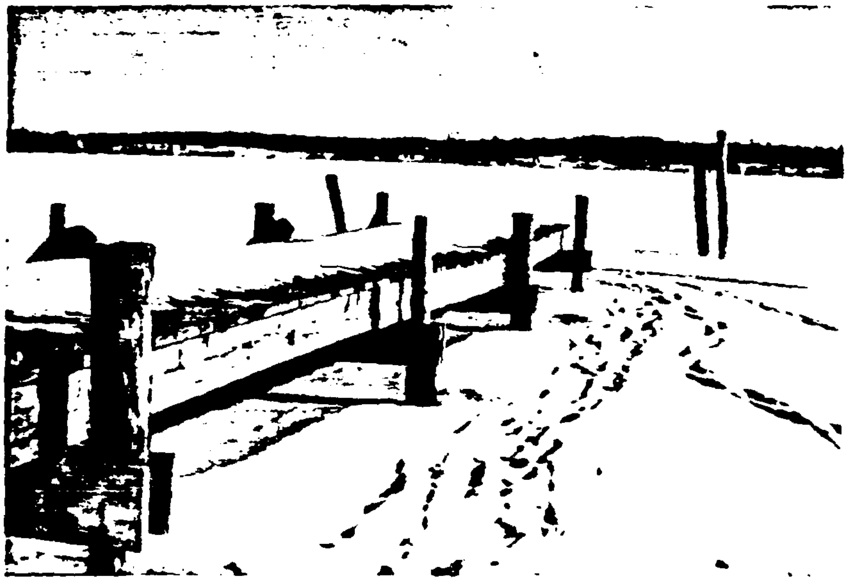

Figure 49. Dark Hole pile dock.

very well during both winters they were in place. The original Franklin Resort dock which can be seen on the left side of Figure 47 (9 February 1980) experienced no perceptible damage during the winter season.

Johnsons Point. Another site which has suffered significant damage during previous winter navigation seasons is the Little Neebish Resort just upstream from Johnsons Point on Neebish Island. Its location is indicated on the aerial photo in Figure 44. Figure 50 is an aerial view of the area

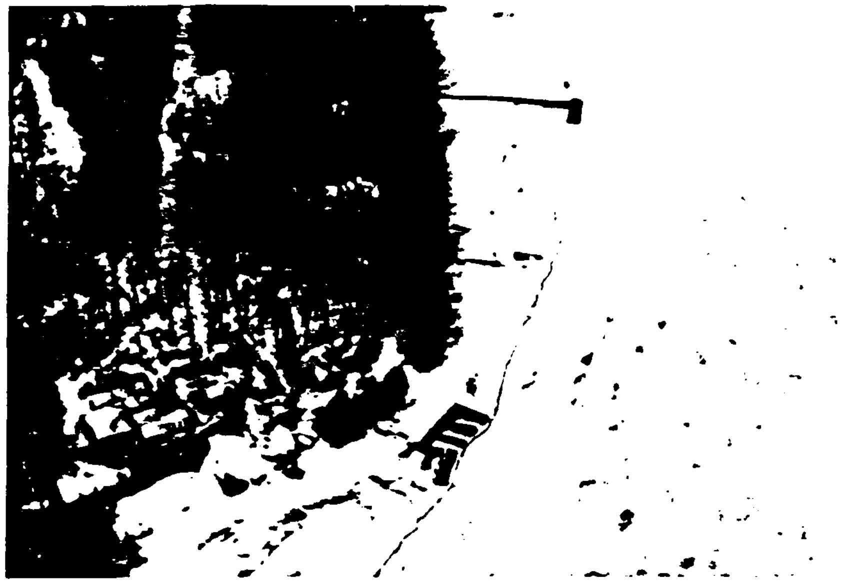

Figure 50. Aerial view, Johnsons Point.

Figure 51. Spreading of finger piers by ice action.

from the 1977 navigation season and shows a large shore-parallel active crack passing just offshore of the structure. Other cracks passed through the structure resulting in the spreading of the finger piers shown in Figure 50 and 51.

During last year's closed navigation season these cracks were not evident. Figure 52 shows conditions several weeks after the close of navigation. No active cracks were evident. The uplifted docks shown in Figure

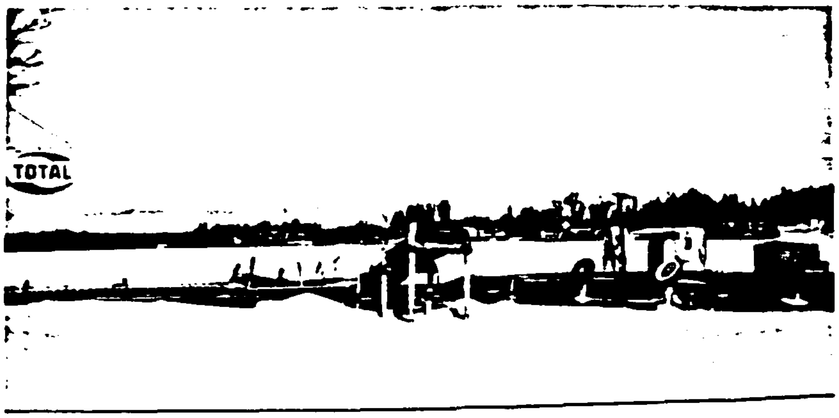

Figure 52. Little Neebish Resort at beginning of closed navigation season.

Figure 53. Little Neebish Resort with navigation reopened.

52 were in that condition at the close of navigation and no further change was observed during the closed period. Figure 53 taken on 30 March again shows the uplifted finger pier with no further perceptible damage.

Figure 54 shows the docks at the Little neebish Resort at the time of spring breakup. The left side of the structure in this picture is another Corps of Engineers structure which is supported on piles of various composition. It sustained no perceptible damage throughout the winter

Figure 54. Little Neebish Resort during spring breakup.

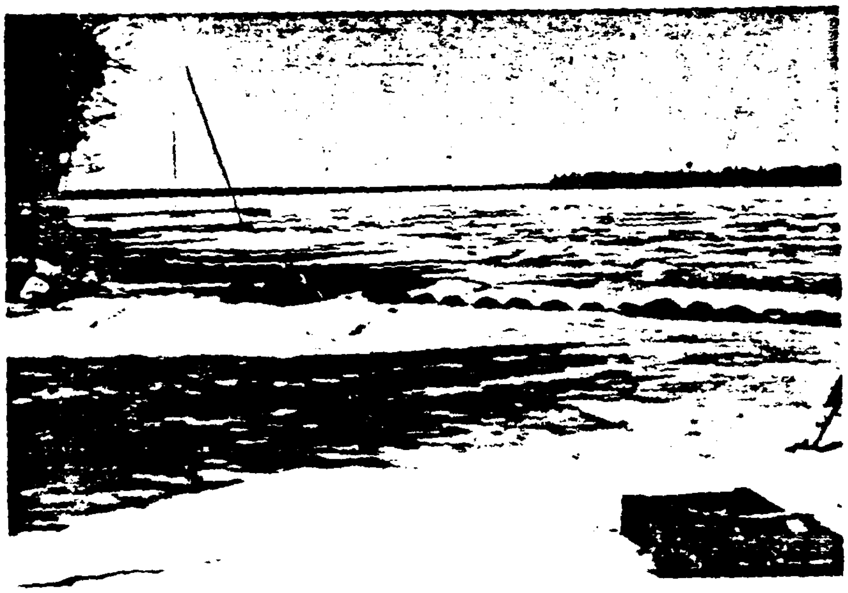

Figure 55. Shore-fast ice and tire boom at Little Neebish Resort.

season. Note the large floating ice masses in the foreground. These were prevented from flowing against the docks by an intact area of shorefast ice upstream as shown in Figure 55 which also shows a tire boom which was another Corps of Engineers project in 1978-79 to control ice.

Detour. Figures 56 and 57 show the condition of a series of small docks near the mainland Drummond Island Ferry dock on 25 January 1980. Some uplift is apparent, but as shown in Figures 58 and 59 taken on 15

Figure 56. Small docks at Detour after close of navigation.

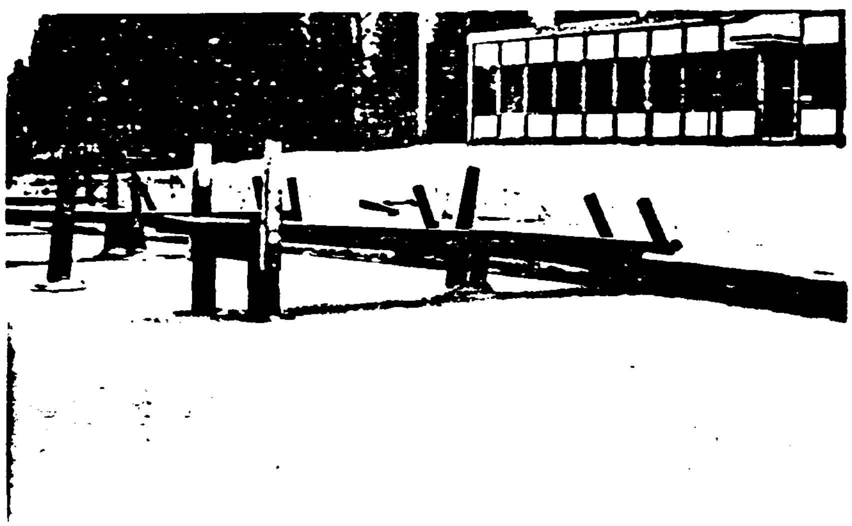

Figure 57. Small dock at Detour after close of navigation.

March 1980 near the end of the closed navigation season, no further damage was apparent through the closed navigation period.

Another nearby dock (referred to as the Lake Carriers Dock) is shown in Figures 60 and 61. Figure 60 was taken on 25 January 1980 while Figure 61 was from 15 March 1980. There was no perceptible damage to this portion of the dock.

Figure 62 and 63 shown another portion of this same general structure on 25 January 1980, which has sustained some damage due to horizontal

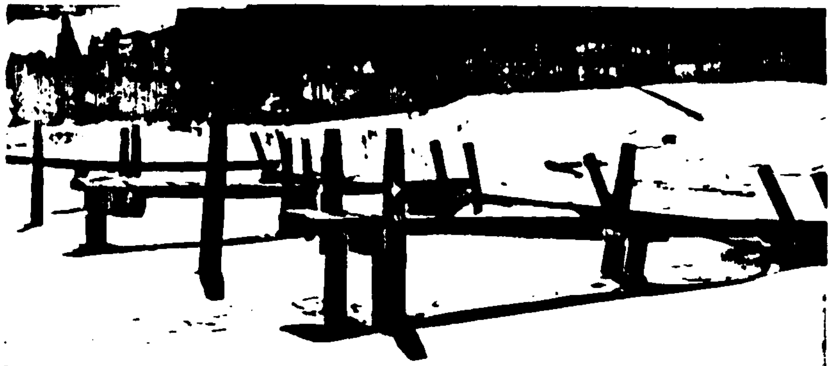

Figure 58. Small docks at Detour near opening of navigation.

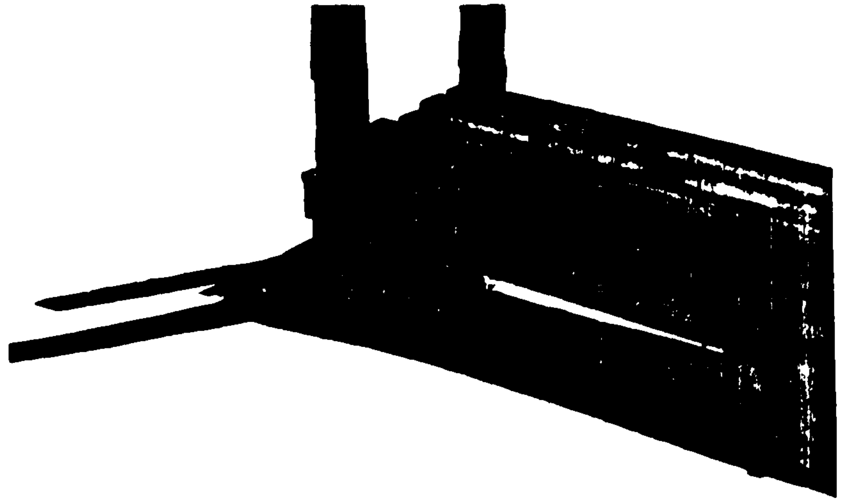

Figure 59. Small dock at Detour near opening of navigation.

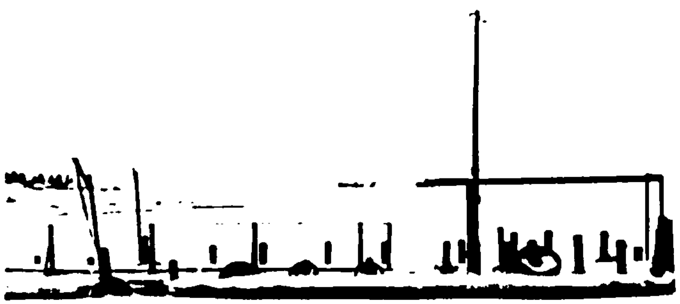

Figure 60. Lake carriers dock after close of navigation.

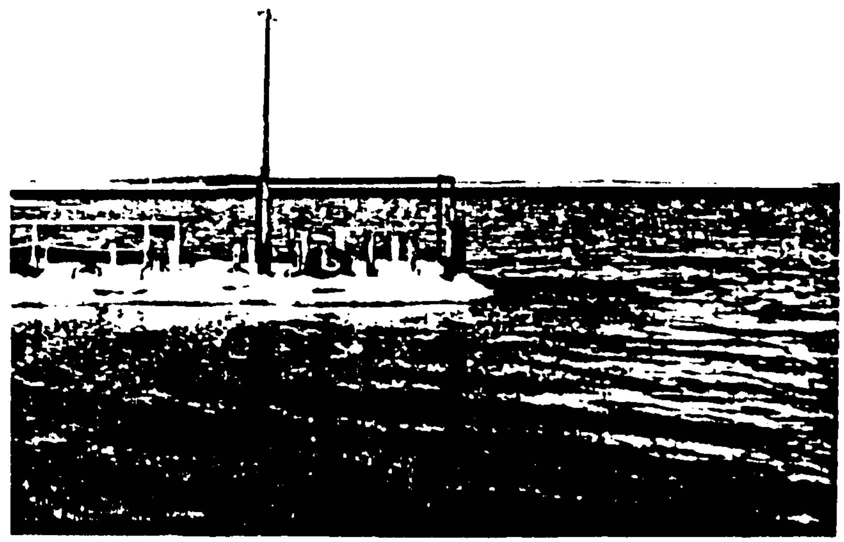

Figure 61. Lack carrier dock near reopening of navigation.

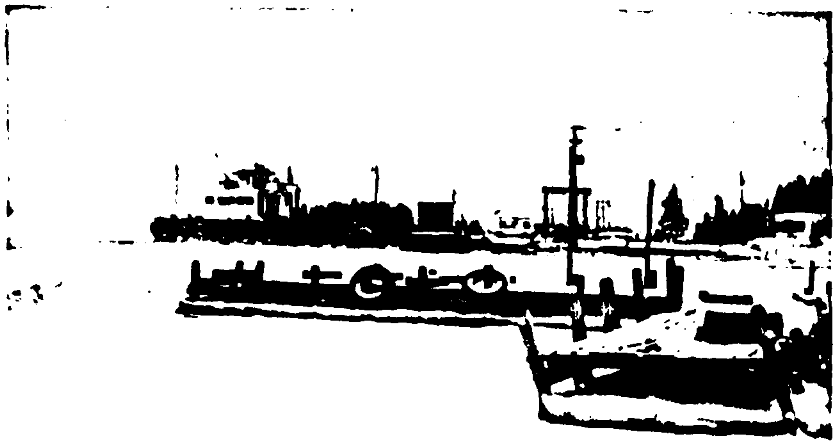

Figure 62. Damaged lake carrier dock.

Figure 63. Damaged lake carrier dock with fishing boat.

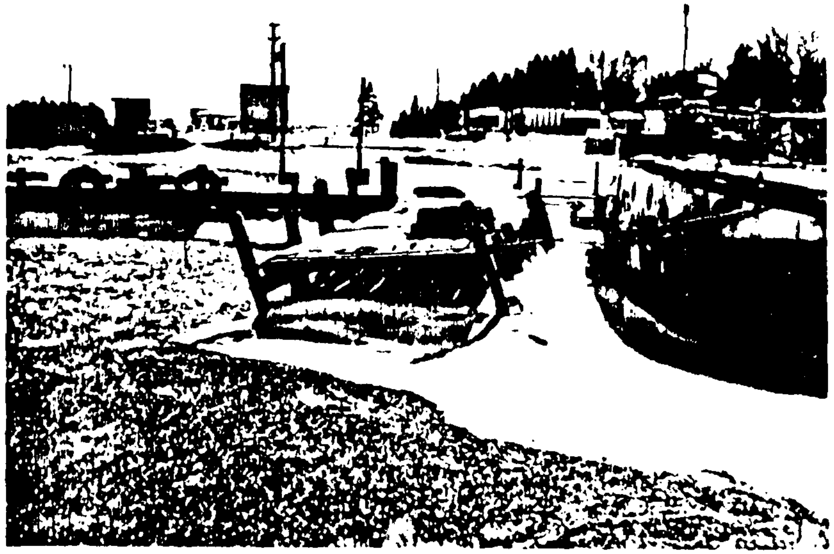

Figure 64. Damaged lake carrier dock near opening of navigation.

forces (possibly ice) prior to the closed navigation season. The Drummond Island Ferry can be seen in the background of Figure 62. Figure 64 shows this same structure on 15 March 1980 near ice out with no further apparent damage.

CONCLUSIONS AND RECOMMENDATIONS

It is evident from the information reported here related to similar data reported from previous years that nearshore and bluff recession continues at sites which have previously been reported as active. However, one site, which previously was relatively inactive now shows some erosion activity. Since winter navigation was essentially absent during this present study period and active during the periods covered by previous reports the combined evidence appears to be inadequate to factor winter navigation effects, if any. If erosive forces are present relative to winter navigation activity, they could only be factored by a more intensive study including both summer and winter periods at a much more frequent interval. should a future monitoring program be established it is essential that the frequency of observatios be considerably expanded.

Although some docks were found to be in a damaged condition at the beginning of the closed navigation period, none of the monitored docks appeared to have sustained damage during the period of study. Previous experience indicates that the greatest damage occurs when the ice thickness is from 0 to 6 inches. Since this range of ice thickness was surpassed before the close of navigation damage which occurred during this critical period could not be addressed. In addition, spring breakup occured after navigation was resumed.

Another topic which should be studied is the effect of witner navigation on ice production. Continuing ice breaking by vessel passage with subsequent refreezing can increase the amount of ice present in the river. In addition, the horizontal jacking of the ice cover towards the channel mentioned in an earlier section can further increase the quantity of ice. This added ice can substantially effect water levels and flow velocities in the river, which in turn can affect the magnitude of vessel effects.